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(54) Title: SYNTHETIC HPV6/11 HYBRID L1 DNA ENCODING HUMAN PAPILLOMAVIRUS TYPE 11 L1 PROTEIN

(57) Abstract

The present invention is directed to a synthetic DNA molecule encoding purified human papillomavirus type 11 L1 protein and derivatives thereof.

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TITLE OF THE INVENTION

SYNTHETIC HPV6/11 HYBRID L1 DNA ENCODING HUMAN PAPILLOMAVIRUS TYPE 11 L1 PROTEIN

CROSS-RELATED TO OTHER APPLICATIONS

This is a continuation of U.S. Serial No. 08/413,572 filed March 30, 1995, now pending, and a continuation of U.S. Serial No. 08/413,571 filed March 30, 1995, now pending.

FIELD OF THE INVENTION

The present invention is directed to a synthetic DNA molecule encoding purified human papillomavirus type 11 L1 protein and derivatives thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic of the construction of the HPV6/11 hybrid L1 gene using synthetic oligonucleotides.

Figure 2 shows the nucleotide sequence of the HPV6/11 hybrid, published HPV6a and published HPV11 L1 genes.

Figure 3 shows the bidirectional yeast expression vector pGAL1-10 used to express papillomavirus L1 capsid proteins.

Figure 4 is a Northern analysis of HPV11 L1 mRNA from yeast.

Figure 5 shows expression of HPV11 L1 protein in yeast by Western analysis (immunoblot).

Figure 6 shows ELISA reactivities of HPV11 L1 VLPs expressed from wild-type (wt) HPV11 compared to HPV6/11 hybrid DNA.

Figure 7 is an electron micrograph of HPV11 L1 VLPs expressed in yeast.

Figure 8 shows the nucleotide sequence of the HPV6/11 hybrid gene.

## BACKGROUND OF THE INVENTION

Papillomavirus (PV) infections occur in a variety of animals, including humans, sheep, dogs, cats, rabbits, monkeys, snakes and cows. Papillomaviruses infect epithelial cells, generally inducing benign epithelial or fibroepithelial tumors at the site of infection. PV are species specific infective agents; a human papillomavirus cannot infect a nonhuman animal.

Papillomaviruses may be classified into distinct groups based on the host that they infect. Human papillomaviruses (HPV) are further classified into more than 70 types based on DNA sequence homology. PV types appear to be type-specific immunogens in that a neutralizing immunity to infection by one type of papillomavirus does not confer immunity against another type of papillomavirus.

In humans, different HPV types cause distinct diseases. HPV types 1, 2, 3, 4, 7, 10 and 26-29 cause benign warts in both normal and immunocompromised individuals. HPV types 5, 8, 9, 12, 14, 15, 17, 19-25, 36 and 46-50 cause flat lesions in immunocompromised individuals. HPV types 6, 11, 34, 39, 41-44 and 51-55 cause nonmalignant condylomata of the genital or respiratory mucosa. HPV types 16, 18, 31, 33, 35, 45, and 58 cause epithelial dysplasia of the genital mucosa and are associated with the majority of *in situ* and invasive carcinomas of the cervix, vagina, vulva and anal canal.

Papillomaviruses are small (50-60 nm), nonenveloped, icosahedral DNA viruses that encode for up to eight early and two late genes. The open reading frames (ORFs) of the virus genomes are designated E1 to E8 and L1 and L2, where "E" denotes early and "L" denotes late. L1 and L2 code for virus capsid proteins. The early (E) genes are associated with functions such as viral replication, transcriptional regulation and cellular transformation.

The L1 protein is the major capsid protein and has a molecular weight of 55-60 kDa. L2 protein is a minor capsid protein which has a predicted molecular weight of 55-60 kDa and an apparent molecular weight of 75-100 kDa as determined by polyacrylamide gel electrophoresis. Immunological data suggest that most of the L2 protein

is internal to the L1 protein within the viral capsomere. The L1 ORF is highly conserved among different papillomaviruses. The L2 proteins are less conserved among different papillomaviruses.

The L1 and L2 genes have been identified as good targets for immunoprophylaxis. Some of the early genes have also been demonstrated to be potential targets of vaccine development. Studies in the cottontail rabbit papillomavirus (CRPV) and bovine papillomavirus (BPV) systems have shown that immunizations with recombinant L1 and/or L2 proteins (produced in bacteria or by using vaccinia vectors) protected animals from viral infection. Expression of papillomavirus L1 genes in baculovirus expression systems or using vaccinia vectors resulted in the assembly of virus-like particles (VLP) which have been used to induce high-titer virus-neutralizing antibody responses that correlate with protection from viral challenge. Furthermore, the L1 and L2 genes have been used to generate vaccines for the prevention and treatment of papillomavirus infections in animals.

The development and commercialization of prophylactic and therapeutic vaccines for PV infection and disease containing L1 protein, L1 + L2 proteins, or modified L1 or L1 + L2 proteins has been hindered by the lack of large quantities of purified virus and purified protein. Because PV is not readily cultivated *in vitro*, it is difficult to produce the required amounts of L1 and L2 protein by *in vitro* propagation of PV. The resultant supply problems make it difficult to characterize PV and PV proteins. Accordingly, it would be useful to develop a readily renewable source of crude PV proteins, especially PV L1 and L2 proteins or modified L1 and L2 proteins. It would also be useful to develop methods of purifying large quantities of the crude papillomavirus proteins to levels of purity suitable for immunological studies and vaccine development. It would also be useful to produce large quantities of papillomavirus proteins having the immunity-conferring properties of the native proteins, such as the conformation of the native protein. In addition, it would be useful to develop methods of analyzing the PV proteins and methods of determining the relative purity of the proteins as well as compositions containing the proteins. Such highly purified

proteins would also be useful in the preparation of a variety of reagents useful in the study of PV infection; such reagents include but are not limited to polyclonal antibodies, monoclonal antibodies, and analytical standards.

HPV6 and 11 are causative agents for ~90% of benign genital warts and are only rarely associated with malignancies (Gissmann *et al.*, 1983, *PNAS* 80, 560-563). HPV6a is considered to be the most abundant HPV6 subtype in condyloma accuminata (Brown, D. B., *et al.*, *J. Clin. Microbiol.* 31:1667-1673). Office visits for genital warts (condyloma accuminatum or planum) have been on the rise in recent years. It is estimated that ~ 10% of the general population (ages 15-49) have genital-tract HPV infections (Koutsky *et al.* 1988, *Epidemiol.* Rev. 10, 122-163). While the majority of condylomata is associated with HPV6, in the case of laryngeal papillomatosis, HPV11 is the dominant type. HPV11 replication in the epithelial cells of the respiratory tract stimulates the proliferation of these cells which can lead to isolated lesions of minor clinical relevance or to multiple spreading lesions and recurring disease. Recurrent respiratory papillomatosis, a disease which more often afflicts the juvenile population, can be a life-threatening disease by causing obstructions in the respiratory tract. Recently, an animal model which allows the replication of infectious HPV11, has been developed (Kreider *et al.* 1985, *Nature* 317, 639-640; Kreider *et al.* 1987, *J. Virol.* 61, 590-593). The model enabled the identification of conformational neutralizing epitopes on native virions and baculovirus-expressed VLPs using monoclonal antibodies (Christensen *et al* 1990, *J. Virol.* 64, 5678-5681; Christensen and Kreider 1991, *Virus Res.* 21, 169-179; Christensen and Kreider 1993, *Virus Res.* 28, 195-202; Christensen *et al.* 1994, 75, 2271-2276).

Virus-like particles containing HPV11 L1 protein have been expressed in both insect and mammalian cell systems. Expression of VLPs in yeast cells offers the advantages of being cost-effective and easily adapted to large-scale growth in fermenters. However, the HPV11 L1 protein is expressed at low levels in yeast cells. This was observed to be a result of truncation of the HPV11 L1 mRNA. In contrast, the HPV6

L1 gene is transcribed as full-length mRNA and is expressed to high levels. By modifying the HPV6 L1 DNA to encode the HPV11 L1 protein, it is possible to facilitate the transcription of full-length mRNA resulting in increased HPV11 L1 protein expression. The present invention provides an HPV6/11 hybrid L1 gene sequence as well as a method for the construction of the HPV6/11 hybrid L1 gene using synthetic oligonucleotides. The hybrid gene was designed using the HPV6a L1 sequence (Hofmann, K. J., *et al.*, 1995, *Virology*, accepted for publication) but contains the minimal number of base changes necessary to encode the HPV11 L1 protein. Unlike the wild-type HPV11 L1 gene, the HPV6/11 hybrid gene does not contain yeast-recognized internal transcription termination signals; as a result full-length HPV6/11 mRNA is produced and expression of HPV11 L1 protein is increased.

The present invention is directed to highly purified PV L1 protein. The invention also comprises methods by which recombinant papillomavirus proteins having the immunity-conferring properties of the native papillomavirus proteins are produced and purified. The present invention is directed to the production of prophylactic and therapeutic vaccines for papillomavirus infection. Electron microscopy and binding to conformational antibodies demonstrate that the recombinant proteins of the present invention are capable of forming virus-like particles.

## SUMMARY OF THE INVENTION

The present invention is directed to a synthetic DNA molecule encoding purified human papillomavirus type 11 L1 protein and derivatives thereof.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a synthetic DNA molecule encoding purified human papillomavirus type 11 L1 protein and derivatives thereof. Various embodiments of the invention include but are not limited to recombinant HPV DNA molecules, RNA complementary to the recombinant HPV DNA molecules, proteins encoded by the recombinant DNA molecules, antibodies to the

recombinant DNA molecules and related proteins, compositions comprising the DNA, RNA, proteins or antibodies, methods of using the DNA, RNA, proteins or antibodies as well as derivatives thereof. Such derivatives include but are not limited to peptides and proteins encoded by the DNA, antibodies to the DNA or antibodies to the proteins encoded by the DNA, vaccines comprising the DNA or vaccines comprising proteins encoded by the DNA, immunological compositions comprising the DNA or the proteins encoded by the DNA, kits containing the DNA or RNA derived from the DNA or proteins encoded by the DNA.

HPV6 and11 are causative agents for ~90% of benign genital warts and are only rarely associated with malignancies (Gissmann *et al.*, 1983, *PNAS* 80, 560-563). Office visits for genital warts (condyloma accuminatum or planum) have been on the rise in the last years and it is estimated that ~ 10% of the general population (ages 15-49) have genital-tract HPV infections (Koutsky *et al.* 1988, *Epidemiol.* Rev. 10, 122-163). While the majority of condylomata is associated with HPV6, in the case of laryngeal papillomatosis, HPV11 is the dominant type. HPV11 replication in the epithelial cells of the respiratory tract stimulates the proliferation of these cells which can lead to isolated lesions of minor clinical relevance or to multiple spreading lesions and recurring disease. Recurrent respiratory papillomatosis, a disease which more often afflicts the juvenile population, can be a life-threatening disease by causing obstructions in the respiratory tract. Recently, an animal model which allows the replication of infectious HPV11, has been developed (Kreider *et al.* 1985, *Nature* 317, 639-640; Kreider *et al.* 1987, *J. Virol.* 61, 590-593). The model enabled the identification of conformational neutralizing epitopes on native virions and baculovirus-expressed VLPs using monoclonal antibodies (Christensen *et al.* 1990, *J. Virol* 64, 5678-5681; Christensen and Kreider 1991, *Virus-Res.* 21, 169-179; Christensen and Kreider 1993, *Virus Res.* 28, 195-202; Christensen *et al.* 1994, 75, 2271-2276).

The development and commercialization of prophylactic and therapeutic vaccines for PV infection and disease containing L1 protein, L1 + L2 proteins, or modified L1 or L1 + L2 proteins has been hindered

by the lack of large quantities of purified virus and purified protein. Because PV is not readily cultivated *in vitro*, it is difficult to produce the required amounts of L1 and L2 protein by *in vitro* propagation of PV. The difficulties associated with *in vitro* cultivation of PV also result in difficulties in chemical, immunological and biological characterization of PV and PV proteins. Accordingly, it would be useful to develop a readily renewable source of crude PV proteins, especially PV L1 and L2 proteins or modified L1 and L2 proteins. It would also be useful to develop methods of purifying large quantities of the crude papillomavirus proteins to levels of purity suitable for immunological studies and vaccine development. It would also be useful to produce large quantities of papillomavirus proteins having the immunity-conferring properties of the native proteins, such as the conformation of the native protein. In addition, it would be useful to develop methods of analyzing the PV proteins and methods of determining the relative purity of the proteins as well as compositions containing the proteins. Such highly purified proteins would also be useful in the preparation of a variety of reagents useful in the study of PV infection; such reagents include but are not limited to polyclonal antibodies, monoclonal antibodies, and analytical standards.

Virus-like particles containing HPV11 L1 protein have been expressed in both insect and mammalian cell systems. Expression of VLPs in yeast cells offers the advantages of being cost-effective and easily adapted to large-scale growth in fermenters. However, the HPV11 L1 protein is expressed at low levels in yeast cells. This was observed to be a result of truncation of the HPV11 L1 mRNA. In contrast, the HPV6 L1 gene is transcribed as full-length mRNA and is expressed to high levels. By modifying the HPV6 L1 DNA to encode the HPV11 L1 protein, it is possible to facilitate the transcription of full-length mRNA resulting in increased HPV11 L1 protein expression. The present invention provides an HPV6/11 hybrid L1 gene as well as a method for the construction of the HPV6/11 hybrid L1 gene using synthetic oligonucleotides. The hybrid gene was designed using the HPV6a L1 sequence but contains the minimal number of base changes necessary to

encode the HPV11 L1 protein. Unlike the wild-type HPV11 L1 gene, the HPV6/11 hybrid gene does not contain yeast-recognized internal transcription termination signals, resulting in higher levels of mRNA and consequently increased HPV11 L1 protein expression.

Pharmaceutically useful compositions comprising the DNA or proteins encoded by the DNA may be formulated according to known methods such as by the admixture of a pharmaceutically acceptable carrier. Examples of such carriers and methods of formulation may be found in Remington's Pharmaceutical Sciences. To form a pharmaceutically acceptable composition suitable for effective administration, such compositions will contain an effective amount of the protein or VLP. Such compositions may contain proteins or VLP derived from more than one type of HPV.

Therapeutic or diagnostic compositions of the invention are administered to an individual in amounts sufficient to treat or diagnose PV infections. The effective amount may vary according to a variety of factors such as the individual's condition, weight, sex and age. Other factors include the mode of administration. Generally, the compositions will be administered in dosages ranging from about 1 mcg to about 1 mg.

The pharmaceutical compositions may be provided to the individual by a variety of routes such as subcutaneous, topical, oral, mucosal, intravenous and intramuscular.

The vaccines of the invention comprise DNA, RNA or proteins encoded by the DNA that contain the antigenic determinants necessary to induce the formation of neutralizing antibodies in the host. Such vaccines are also safe enough to be administered without danger of clinical infection; do not have toxic side effects; can be administered by an effective route; are stable; and are compatible with vaccine carriers.

The vaccines may be administered by a variety of routes, such as orally, parenterally, subcutaneously, mucosally, intravenously or intramuscularly. The dosage administered may vary with the condition, sex, weight, and age of the individual; the route of administration; and the type PV of the vaccine. The vaccine may be used in dosage forms such

as capsules, suspensions, elixirs, or liquid solutions. The vaccine may be formulated with an immunologically acceptable carrier.

The vaccines are administered in therapeutically effective amounts, that is, in amounts sufficient to generate a immunologically protective response. The therapeutically effective amount may vary according to the type of PV. The vaccine may be administered in single or multiple doses.

The purified proteins of the present invention may be used in the formulation of immunogenic compositions. Such compositions, when introduced into a suitable host, are capable of inducing an immune response in the host.

The purified proteins of the invention or derivatives thereof may be used to generate antibodies. The term "antibody" as used herein includes both polyclonal and monoclonal antibodies, as well as fragments thereof, such as, Fv, Fab and F(ab)2 fragments that are capable of binding antigen or hapten.

The proteins and protein derivatives of the present invention may be used to serotype HPV infection and HPV screening. The purified proteins, VLP and antibodies lend themselves to the formulation of kits suitable for the detection and serotyping of HPV. Such a kit would comprise a compartmentalized carrier suitable to hold in close confinement at least one container. The carrier may further comprise reagents such as L1 or L2 proteins or VLPs derived from recombinant HPV6/11 or other recombinant HPV type DNA molecules or antibodies directed against these proteins. The carrier may also contain means for detection such as labeled antigen or enzyme substrates or the like.

The purified proteins are also useful as immunological standards, molecular weight markers and molecular size markers.

It is known that there is a substantial amount of redundancy in the various codons which code for specific amino acids. Therefore, this invention is also directed to those DNA sequences which contain alternative codons which code for the eventual translation of the identical amino acid. For purposes of this specification, a sequence bearing one or more replaced codons will be defined as a degenerate variation. Also

included within the scope of this invention are mutations either in the DNA sequence or the translated protein which do not substantially alter the ultimate physical properties of the expressed protein. For example, substitution of valine for leucine, arginine for lysine, or asparagine for glutamine may not cause a change in functionality of the polypeptide.

It is known that DNA sequences coding for a peptide may be altered so as to code for a peptide having properties that are different than those of the naturally-occurring peptide. Methods of altering the DNA sequences include, but are not limited to site directed mutagenesis.

As used herein, a "functional derivative" of the HPV6/11 hybrid gene is a compound that possesses a biological activity (either functional or structural) that is substantially similar to the biological activity of HPV6/11. The term "functional derivatives" is intended to include the "fragments," "variants," "degenerate variants," "analogs" and "homologues" or to "chemical derivatives" of HPV6/11.

The term "analog" refers to a molecule substantially similar in function to either the entire HPV6/11 molecule or to a fragment thereof.

The cloned HPV6/11 DNA or fragments thereof obtained through the methods described herein may be recombinantly expressed by molecular cloning into an expression vector containing a suitable promoter and other appropriate transcription regulatory elements, and transferred into prokaryotic or eukaryotic host cells to produce recombinant HPV11. Techniques for such manipulations are fully described in Sambrook, J., *et al.*, *supra*, and are known in the art.

Expression vectors are defined herein as DNA sequences that are required for the transcription of cloned copies of genes and the translation of their mRNAs in an appropriate host. Such vectors can be used to express eukaryotic genes in a variety of hosts such as bacteria, bluegreen algae, plant cells, insect cells, fungal cells and animal cells. Specifically designed vectors allow the shuttling of DNA between hosts such as bacteria-yeast or bacteria-animal cells or bacteria-fungal cells or bacteria-invertebrate cells. An appropriately constructed expression vector should contain: an origin of replication for autonomous replication

in host cells, selectable markers, a limited number of useful restriction enzyme sites, a potential for high copy number, and active promoters. A promoter is defined as a DNA sequence that directs RNA polymerase to bind to DNA and initiate RNA synthesis. A strong promoter is one which causes mRNAs to be initiated at high frequency. Expression vectors may include, but are not limited to, cloning vectors, modified cloning vectors, specifically designed plasmids or viruses.

A variety of mammalian expression vectors may be used to express HPV6/11 DNA or fragments thereof in mammalian cells. Commercially available mammalian expression vectors which may be suitable for recombinant HPV6/11 DNA expression, include but are not limited to, pcDNA3 (Invitrogen), pMC1neo (Stratagene), pXT1 (Stratagene), pSG5 (Stratagene), EBO-pSV2-neo (ATCC 37593) pBPV-1(8-2) (ATCC 37110), pdBPV-MMTneo(342-12) (ATCC 37224), pRSVgpt (ATCC 37199), pRSVneo (ATCC 37198), pSV2-dhfr (ATCC 37146), pUCTag (ATCC 37460), and λZD35 (ATCC 37565).

A variety of bacterial expression vectors may be used to express HPV6/11 DNA or fragments thereof in bacterial cells. Commercially available bacterial expression vectors which may be suitable for recombinant HPV6/11 DNA expression include, but are not limited to pET11a (Novagen), lambda gt11 (Invitrogen), pcDNAII (Invitrogen), pKK223-3 (Pharmacia).

A variety of fungal cell expression vectors may be used to express HPV6/11 or fragments thereof in fungal cells. Commercially available fungal cell expression vectors which may be suitable for recombinant HPV6/11 DNA expression include but are not limited to pYES2 (Invitrogen), *Pichia* expression vector (Invitrogen) and *Hansenula* expression (Rhein Biotech, Dusseldorf, Germany).

A variety of insect cell expression vectors may be used to express HPV6/11 DNA or fragments thereof in insect cells. Commercially available insect cell expression vectors which may be suitable for recombinant expression of HPV6/11 DNA include but are not limited to pBlue Bac III (Invitrogen).

An expression vector containing HPV 6/11 DNA or fragments thereof may be used for expression of HPV11 proteins or fragments of HPV11 proteins in a cell, tissue, organ, or animal. Animal, as used herein, includes humans. Host cells may be prokaryotic or eukaryotic, including but not limited to bacteria such as *E. coli*, fungal cells such as yeast, mammalian cells including but not limited to cell lines of human, bovine, porcine, monkey and rodent origin, and insect cells including but not limited to Drosophila and silkworm derived cell lines. Cell lines derived from mammalian species which may be suitable and which are commercially available, include but are not limited to, L cells L-M(TK$^-$) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), 293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I (ATCC CRL 1616), BS-C-1 (ATCC CCL 26) and MRC-5 (ATCC CCL 171).

The expression vector may be introduced into host cells via any one of a number of techniques including but not limited to transformation, transfection, lipofection, protoplast fusion, and electroporation. The expression vector-containing cells are clonally propagated and individually analyzed to determine whether they produce HPV11 protein. Identification of HPV11 expressing host cell clones may be done by several means, including but not limited to immunological reactivity with anti-HPV11 antibodies.

Expression of HPV DNA fragments may also be performed using *in vitro* produced synthetic mRNA or native mRNA. Synthetic mRNA or mRNA isolated from cells expressing HPV6/11 hybrid DNA can be efficiently translated in various cell-free systems, including but not limited to wheat germ extracts and reticulocyte extracts, as well as efficiently translated in cell based systems, including but not limited to microinjection into frog oocytes, with microinjection into frog oocytes being preferred.

Following expression of HPV11 protein in a host cell, HPV11 protein may be recovered to provide HPV11 protein in purified

form. Several HPV11 purification procedures are available and suitable for use. As described herein, recombinant HPV11 protein may be purified from cell lysates and extracts by various combinations of, or individual application of salt fractionation, ion exchange chromatography, size exclusion chromatography, hydroxylapatite adsorption chromatography and hydrophobic interaction chromatography.

In addition, recombinant HPV11 protein may be separated from other cellular proteins by use of an immunoaffinity column made with monoclonal or polyclonal antibodies specific for full length nascent HPV11, or polypeptide fragments of HPV11. Monoclonal and polyclonal antibodies may be prepared according to a variety of methods known in the art. Monoclonal or monospecific antibody as used herein is defined as a single antibody species or multiple antibody species with homogenous binding characteristics for HPV11. Homogenous binding as used herein refers to the ability of the antibody species to bind to a specific antigen or epitope.

It is apparent to those skilled in the art that the methods for producing monospecific antibodies may be utilized to produce antibodies specific for HPV polypeptide fragments, or full-length nascent HPV polypeptides. Specifically, it is apparent to those skilled in the art that monospecific antibodies may be generated which are specific for the fully functional HPV proteins or fragments thereof.

The present invention is also directed to methods for screening for compounds which modulate the expression of DNA or RNA encoding HPV as well as the function(s) of HPV11 protein *in vivo*. Compounds which modulate these activities may be DNA, RNA, peptides, proteins, or non-proteinaceous organic molecules. Compounds may modulate by increasing or attenuating the expression of DNA or RNA encoding HPV11, or the function of HPV11 protein. Compounds that modulate the expression of DNA or RNA encoding HPV11 or the function of HPV11 protein may be detected by a variety of assays. The assay may be a simple "yes/no" assay to determine whether there is a change in expression or function. The assay may be made quantitative by

comparing the expression or function of a test sample with the levels of expression or function in a standard sample.

Kits containing HPV6/11 hybrid DNA, fragments of HPV6/11 hybrid DNA, antibodies to HPV6/11 DNA or HPV11 protein, HPV6/11 hybrid RNA or HPV11 protein may be prepared. Such kits are used to detect DNA which hybridizes to HPV6/11 DNA or to detect the presence of HPV11 protein or peptide fragments in a sample. Such characterization is useful for a variety of purposes including but not limited to forensic analyses and epidemiological studies.

Nucleotide sequences that are complementary to the HPV6/11 DNA sequence may be synthesized for antisense therapy. These antisense molecules may be DNA, stable derivatives of DNA such as phosphorothioates or methylphosphonates, RNA, stable derivatives of RNA such as 2'-*O*-alkylRNA, or other HPV6/11 antisense oligonucleotide mimetics. HPV6/11 antisense molecules may be introduced into cells by microinjection, liposome encapsulation or by expression from vectors harboring the antisense sequence. HPV6/11 antisense therapy may be particularly useful for the treatment of diseases where it is beneficial to reduce HPV11 activity.

The term "chemical derivative" describes a molecule that contains additional chemical moieties which are not normally a part of the base molecule. Such moieties may improve the solubility, half-life, absorption, etc. of the base molecule. Alternatively the moieties may attenuate undesirable side effects of the base molecule or decrease the toxicity of the base molecule. Examples of such moieties are described in a variety of texts, such as Remington's Pharmaceutical Sciences.

Compounds identified according to the methods disclosed herein may be used alone at appropriate dosages defined by routine testing in order to obtain optimal inhibition of the HPV11 or its activity while minimizing any potential toxicity. In addition, co-administration or sequential administration of other agents may be desirable.

Advantageously, compounds of the present invention may be administered in a single dose, or the total dosage may be administered in several divided doses. Furthermore, compounds for the present invention

may be administered via a variety of routes including but not limited to intranasally, transdermally, by suppository, orally, and the like.

For combination treatment with more than one active agent, where the active agents are in separate dosage formulations, the active agents can be administered concurrently, or they each can be administered at separately staggered times.

The dosage regimen utilizing the compounds of the present invention is selected in accordance with a variety of factors including type, species, age, weight, sex and medical condition of the patient; the severity of the condition to be treated; the route of administration; the renal and hepatic function of the patient; and the particular compound thereof employed. A physician of ordinary skill can readily determine and prescribe the effective amount of the drug required to prevent, counter or arrest the progress of the condition. Optimal precision in achieving concentrations of drug within the range that yields efficacy without toxicity requires a regimen based on the kinetics of the drug's availability to target sites. This involves a consideration of the distribution, equilibrium, and elimination of a drug.

In the methods of the present invention, the compounds herein described in detail can form the active ingredient, and may be administered in admixture with suitable pharmaceutical diluents, excipients or carriers (collectively referred to herein as "carrier" materials) suitably selected with respect to the intended form of administration, that is, oral tablets, capsules, elixirs, syrup, suppositories, gels and the like, and consistent with conventional pharmaceutical practices.

For instance, for oral administration in the form of a tablet or capsule, the active drug component can be combined with an oral, non-toxic pharmaceutically acceptable inert carrier such as ethanol, glycerol, water and the like. Moreover, when desired or necessary, suitable binders, lubricants, disintegrating agents and coloring agents can also be incorporated into the mixture. Suitable binders include without limitation, starch, gelatin, natural sugars such as glucose or beta-lactose, corn sweeteners, natural and synthetic gums such as acacia, tragacanth,

sodium alginate, carboxymethylcellulose, polyethylene glycol, waxes and the like. Lubricants used in these dosage forms include, without limitation, sodium oleate, sodium stearate, magnesium stearate, sodium benzoate, sodium acetate, sodium chloride and the like. Disintegrators include, without limitation, starch, methyl cellulose, agar, bentonite, xanthan gum and the like.

For liquid forms the active drug component can be combined in suitably flavored suspending or dispersing agents such as the synthetic and natural gums, for example, tragacanth, acacia, methyl-cellulose and the like. Other dispersing agents which may be employed include glycerin and the like. For parenteral administration, sterile suspensions and solutions are desired. Isotonic preparations which generally contain suitable preservatives are employed when intravenous administration is desired.

Topical preparations containing the active drug component can be admixed with a variety of carrier materials well known in the art, such as, e.g., alcohols, aloe vera gel, allantoin, glycerine, vitamin A and E oils, mineral oil, PPG2 myristyl propionate, and the like, to form, e.g., alcoholic solutions, topical cleansers, cleansing creams, skin gels, skin lotions, and shampoos in cream or gel formulations.

The compounds of the present invention can also be administered in the form of liposome delivery systems, such as small unilamellar vesicles, large unilamellar vesicles and multilamellar vesicles. Liposomes can be formed from a variety of phospholipids, such as cholesterol, stearylamine or phosphatidylcholines.

Compounds of the present invention may also be delivered by the use of monoclonal antibodies as individual carriers to which the compound molecules are coupled. The compounds of the present invention may also be coupled with soluble polymers as targetable drug carriers. Such polymers can include polyvinyl-pyrrolidone, pyran copolymer, polyhydroxypropylmethacryl-amidephenol, polyhydroxy-ethylaspartamidephenol, or polyethyl-eneoxidepolylysine substituted with palmitoyl residues. Furthermore, the compounds of the present invention may be coupled to a class of biodegradable polymers useful in achieving

controlled release of a drug, for example, polylactic acid, polyepsilon caprolactone, polyhydroxy butyric acid, polyorthoesters, polyacetals, polydihydro-pyrans, polycyanoacrylates and cross-linked or amphipathic block copolymers of hydrogels.

The following examples illustrate the present invention without, however, limiting the same thereto.

## EXAMPLE 1

Construction of the Synthetic L1 Gene

The 1.5 kbp open reading frame of HPV11 L1 was constructed using synthetic DNA oligomers ordered from Midland Reagent Company. These oligomers were supplied containing 5' terminal phosphates. A total of 24 oligomers were required and are listed below:

#241-1
5'GAAGATCTCACAAAACAAAATGTGGCGGCCTAGCGACAGCA
CAGTATATGTGCCTCCTCCTAACCCTGTATCCAAAGTTGTTGCC
ACGGATGCTTATGTTAAACGCACCAACATATTTTATCATGCCA
GCAGTTCTAGACTTCTTGCAGTGGGTCATCCTTATT 3' (SEQ ID NO:1)

#2412
5'ATTCCATAAAAAAGGTTAACAAAACTGTTGTGCCAAAGGTGT
CAGGATATCAATACAGAGTATTTAAGGTGGTGTTACCAGATCC
TAACAAATTTGCATTGCCTGACTCGTCTCTTTTTGATCCCACAA
CACAACGTTTGGTATGGGCATGCATGT 3' (SEQ ID NO:2)

#241-3
5'ACATGCATGCACAGGCCTAGAGGTGGGCCGGGGACAGCCAT
TAGGTGTGGGTGTAAGTGGACATCCTTTACTAAATAAATATGA
TGATGTTGAAAATTCAGGGGGTTACGGTGGTAACCCTGGACAG
GATAACAGG 3' (SEQ ID NO:3)

#241-4
5'GTTAATGTAGGTATGGATTATAAACAAACACAATTATGCATG
GTTGGATGTGCCCCCCCTTTGGGCGAGCATTGGGGTAAAGGTA
CACAGTGTAGTAATACATCTGTACAGAATGGTGACTGCCCGC 3'
(SEQ ID NO:4)

#241-5
5'CCTTAGAACTTATTACCAGTGTTATACAGGATGGCGATATGG
TTGACACAGGCTTTGGTGCTATGAATTTTGCTGATTTGCAGACC
AATAAATCAGATGTTCCTCTTGACATATGTGGCACTGTA 3'
(SEQ ID NO:5)

#241-6
5'TGTAAATATCCAGATTATTTACAAATGGCTGCAGACCCATAT
GGTGATAGATTATTTTTTTATCTACGGAAGGAACAAATGTTTGC
CAGACATTTTTTTAACAGGGCTGGTACCCC 3'(SEQ ID NO:6)

#241-7
5'GGGGTACCGTGGGGGAACCTGTGCCTGATGATCTTTTAGTTA
AGGGTGGTAACAATCGCTCGTCTGTAGCGAGTAGTATATATGT
TCACACCCCAAGCGGCTCTTTGGTGTCCTCTGAGGCACA 3'
(SEQ ID NO:7)

#241-8
5'ATTGTTTAATAAGCCATATTGGCTACAAAAAGCCCAGGGACA
TAACAATGGTATTTGTTGGGGTAATCATCTGTTTGTTACTGTGG
TAGATACCACACGCAGTACCAACATGA 3'(SEQ ID NO:8)

#241-9
5'CATTATGTGCATCCGTATCTAAATCTGCCACATACACCAATTC
TGATTATAAAGAGTACATGCGTCATGTGGAAGAGTTTGATTTA
CAATTTATTTTTCAATTATGTAGCATT 3'(SEQ ID NO:9)

#241-10
5'ACATTGTCTGCTGAAGTAATGGCCTATATTCACACAATGAAT
CCCTCTGTTCTCGAGGACTGGAACTTTGGGTTATCGCCTCCCCC
AAATGGTACACTCGAGCGG 3'(SEQ ID NO:10)

#241-11
5'CCGCTCGAGGATACCTATAGGTATGTGCAGTCACAGGCCATT
ACCTGTCAAAAGCCCACTCCTGAAAAGGAAAAGCAAGATCCCT
ATAAGGACATGAGTTTTTGGGAGGTTAATTTAAAAGAAAAGTT
TTCTAGTGAATTGGATCAGTTTCCTTT 3' (SEQ ID NO:11)

#241-12
5'GGGACGCAAGTTTTTGTTACAAAGTGGATATAGGGGACGGAC
CTCTGCTCGTACCGGTATTAAGCGCCCTGCTGTTTCCAAACCCT
CTACTGCCCCTAAACGTAAGCGCACCAAAACTAAAAAGTAAG
ATCTTC 3' (SEQ ID NO:12)

#241-13
5'GAAGATCTTACTTTTTAGTTTTGGTGCGCTTACGTTTAGGGGC
AGTAGAGGGTTTGGAAACAGCAGGGCGCTTAATACCGGTACG
AGCAGAGGTCCGTCCCCTATATCCACTTTGTAACAAAAACTTG
CGTCCCAAAGGAAACTGATCCAATTC 3' (SEQ ID NO:13)

#241-14
5'ACTAGAAAACTTTTCTTTTAAATTAACCTCCCAAAAACTCATG
TCCTTATAGGGATCTTGCTTTTCCTTTTCAGGAGTGGGCTTTTG
ACAGGTAATGGCCTGTGACTGCACATACCTATAGGTATCCTCG
AGCGG 3' (SEQ ID NO:14)

#241-15
5'CCGCTCGAGTGTACCATTTGGGGGAGGCGATAACCCAAAGTT
CCAGTCCTCGAGAACAGAGGGATTCATTGTGTGAATATAGGCC
ATTACTTCAGCAGACAATGTAATGCTACATAATTGAAAAA 3'
(SEQ ID NO:15)

#241-16
5'TAAATTGTAAATCAAACTCTTCCACATGACGCATGTACTCTTT
ATAATCAGAATTGGTGTATGTGGCAGATTTAGATACGGATGCA
CATAATGTCATGTTGGTACTGCGTGTG 3' (SEQ ID NO:16)

#241-17
5'GTATCTACCACAGTAACAAACAGATGATTACCCCAACAAATA
CCATTGTTATGTCCCTGGGCTTTTTGTAGCCAATATGGCTTATT
AAACAATTGTGCCTCAGAGGACACCAA 3' (SEQ ID NO:17)

#241-18
5'AGAGCCGCTTGGGGTGTGAACATATATACTACTCGCTACAGA
CGAGCGATTGTTACCACCCTTAACTAAAAGATCATCAGGCACA
GGTTCCCCCACGGTACCCC 3' (SEQ ID NO:18)

#241-19
5'GGGGTACCAGCCCTGTTAAAAAAATGTCTGGCAAACATTTGT
TCCTTCCGTAGATAAAAAAATAATCTATCACCATATGGGTCTG
CAGCCATTTGTAAATAATCTGGATATTTACATACAGTGCCACA
TATGTCAA 3' (SEQ ID NO:19)

#241-20
5'GAGGAACATCTGATTTATTGGTCTGCAAATCAGCAAAATTCA
TAGCACCAAAGCCTGTGTCAACCATATCGCCATCCTGTATAAC
ACTGGTAATAAGTTCTAAGGGCGGGCAGTCACCATTCTGT 3'
(SEQ ID NO:20)

#241-21
5'ACAGATGTATTACTACACTGTGTACCTTTACCCCAATGCTCGC
CCAAAGGGGGGGCACATCCAACCATGCATAATTGTGTTTGTTT
ATAATCCATACCTACATTAACCCTGTTATCCTGTCCAGGGT 3'
(SEQ ID NO:21)

#241-22
5'TACCACCGTAACCCCCTGAATTTTCAACATCATCATATTTATT
TAGTAAAGGATGTCCACTTACACCCACACCTAATGGCTGTCCC
CGGCCCACCTCTAGGCCTGTGCATGCATGT 3'(SEQ ID NO:22)

#241-23
5'ACATGCATGCCCATACCAAACGTTGTGTTGTGGGATCAAAAA
GAGACGAGTCAGGCAATGCAAATTTGTTAGGATCTGGTAACAC
CACCTTAAATACTCTGTATTGATATCCTGACACCTTTGGCACAA
CAGTTTTGTTAACCTTTTTTATGGAATAATAAGGATGACCC 3'
(SEQ ID NO:23)

#241-24
5'ACTGCAAGAAGTCTAGAACTGCTGGCATGATAAAATATGTTG
GTGCGTTTAACATAAGCATCCGTGGCAACAACTTTGGATACAG
GGTTAGGAGGAGGCACATATACTGTGCTGTCGCTAGGCCGCCA
CATTTTGTTTTGTGAGATCTTC 3' (SEQ ID NO:24)

Oligomers forming complementary pairs (#241-1 and #241-24, #241-2 and #241-23, #241-3 and #241-22, #241-4 and #241-21, #241-5 and #241-20, #241-6 and #241-19, #241-7 and #241-18, #241-8 and #241-17, #241-9 and #241-16, #241-10 and #241-15, #241-11 and #241-14, #241-12 and #241-13- Figure 1) were annealed in separate tubes containing 2.5 mM Tris, pH 7.5, 0.25 mM EDTA. Tubes were heated to 98°C for 4 min and then placed in 200 ml of 98°C water in a 250 ml beaker to cool slowly. When the water cooled to room temperature, the annealed pairs were added to tubes as designated: fragment A (oligomer pairs #241-1 & 24, and -2 & 23); fragment B (#241-3 & 22, -4 & 21, -5 & 20, and -6 &19); fragment C (#241-7 &18, -8 &17, -9 &16 and -10 &15) and fragment D (#241-11 &14 and -12 &13). These oligomer pair mixes were heated to 62°C for 2 min and then cooled slowly as before. The contents of each tube were ligated overnight at 23°C using T4 DNA ligase (Boehringer Mannheim, Inc.) and the reagents supplied by the manufacturer.

After ligation, fragment B required PCR amplification to increase the amount of full-length product. This required ten cycles of 94°C, 1 min; 48°C, 1 min; 72°C, 1 min followed by 10 min at 72°C in an Applied Biosystems thermocycler using Boehringer Mannheim Taq polymerase and the oligomer primers:
5'GGAATTCACATGCATGCACAGGCCTAG 3' (SEQ ID NO:25) and
5' GGAATTCGGGGTACCAGCCCTGTTAA 3' (SEQ ID NO:26).

The ligated products and the fragment B PCR product were digested with restriction enzymes (Boehringer Mannheim, Inc.) as follows: fragment A was digested with Bgl II and Sph I; fragment B, Sph I and Kpn I; fragment C, Kpn I and Xho I; and fragment D, Xho I and Bgl II. The digested fragments were separated on low melting point agarose (FMC BioProducts) gels and correctly sized fragments isolated by excision of the band and digestion of the agarose using Agarase™ (Boehringer Mannheim, Inc.) as recommended by the supplier. The fragments A, B and D were recovered by ethanol precipitation and then separately ligated into the vector pSP72 (Promega, Inc.) that had been similarly digested with restriction enzymes to match each fragment being ligated.

The Kpn I Xho I digested fragment C was first ligated to the annealed oligomers

5'TCGAAGACTGGAACTTTGGGTTATCGCCTCCCCCAAATGGTA CAC 3'; (SEQ ID NO:27) and
5'TCGAGTGTACCATTTGGGGGAGGCGATAACCCAAAGTTCCAG TCT3' (SEQ ID NO:28).

Fragment C was then recleaved with Xho I and the 450 bp KpnI XhoI fragment was ligated with the Kpn I, Xho I-digested pSP72 vector. The ligation mixes were used to transform *Escherichia coli* strain DH5 competent cells (Gibco BRL, Gaithersburg, MD). Transformants were screened for insert-containing clones by colony hybridization (J. Sambrook *et al.*, Molecular Cloning: A Laboratory Manual, 2nd edition,

Cold Spring Harbor Laboratory Press, 1989). Plasmid DNA was isolated from the positive clones using a Wizard miniprep kit (Promega Corp.) and then sequenced using an Applied Biosystems 373A DNA Sequencer. Clones containing the correct DNA sequence for each of the four fragments were digested as before to release the fragments from the pSP72 vector. The Kpn I, Xho I-digested fragment C was ligated with the Xho I, Bgl II-digested fragment D and Kpn I, Bgl II-cut pSP72 in a three-way ligation. The ligation products were then used to transform *E. coli*. Resulting transformants were sequenced and a clone of correct sequence obtained (designated CD). The 750 bp Bgl II Kpn I insert of CD was recleaved from the pSP72 vector and ligated with Bgl II, Sph I -digested fragment A and Sph I, Kpn I-digested fragment B in a three-way ligation as before except Bgl II was added to decrease undesired ligation products. The ligation products were separated on agarose gels, the 1.5 kbp fragment was isolated, and was designated D361-1.

## EXAMPLE 2

Comparison of Sequences

A comparison of the nucleotide sequence for the HPV6/11 hybrid, HPV6a and HPV11 L1 DNA sequences is shown in Figure 2. There are a total of 55 nucleotide substitutions made to the HPV 6 backbone sequence to convert it to a HPV11-encoding translation frame. In addition, three base pair insertions were added at #411-413 bp to encode the additional amino acid (tyrosine$^{132}$) found in HPV11 but not HPV6. Together, these changes allow the type 11-specific, conformation-dependent, neutralizing monoclonal antibody (Chemicon 8740 MAb) to bind the L1 protein of the HPV6/11 L1 DNA expressed in yeast. This suggests that the protein from the HPV6/11 hybrid gene appears to be indistinguishable immunologically from native HPV11.

Comparison of the HPV6/11 hybrid DNA sequence to the published HPV11 L1 sequence shows 194 base pair substitutions. There are a considerable number of substitutions relative to the wild type 11 L1

sequence, any combination of which or all changes in total may be what is responsible for the increased type 11 L1 protein expression in yeast.

## EXAMPLE 3

DNA Sequencing of the L1 gene

The HPV6/11 L1 gene was sequenced using an Applied Biosystems DNA Sequencer #373A with dye terminator sequencing reactions (PRIZM™ Sequencing Kit) as specified by the manufacturer (ABI, Inc., Foster City, CA).

## EXAMPLE 4

Construction of HPV6/11 L1, HPV11 L1 and HPV6 L1 Yeast Expression Vectors

The pGAL1-10 yeast expression vector was constructed by isolating a 1.4 kbp SphI fragment from a pUC18/bidirectional *GAL* promoter plasmid which contains the *Saccharomyces cerevisiae* divergent *GAL1-GAL10* promoters from the plasmid pBM272 (provided by Mark Johnston, Washington University, St. Louis, MO). The divergent promoters are flanked on each side by a copy of the yeast *ADH1* transcriptional terminator (Bennetzen, J.L. and Hall, B.D., 1982, *J. Biol. Chem.* 257: 3018-3025), a BamHI cloning site located between the *GAL1* promoter and the first copy of the *ADH1* transcriptional terminator and a SmaI cloning site located between the *GAL10* promoter and the second copy of the *ADH1* transcriptional terminator. A yeast shuttle vector consisting of pBR322, the yeast *LEU2d* gene (Erhart, E. and Hollenberg, C.P., 1983, *J. Bacteriol.* 156: 625-635) and the yeast 2*u* plasmid (gift of Benjamin Hall, University of Washington, Seattle, WA) (Broach, J.R. and Volkert, F.C., 1991, Circular DNA Plasmids of Yeasts, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York) was digested with SphI and ligated with the 1.4 kbp SphI divergent *GAL* promoter fragment resulting in pGAL1-10 (Figure 3).

The HPV6/11 hybrid L1 DNA encoding the HPV11 L1 protein (sample D361-1 from Example 1) contains a yeast non-translated

leader sequence (Kniskern, P.J. *et al.*, 1986, *Gene* 46: 135-141) immediately upstream to the HPV6/11 L1 initiating methionine codon. The pGAL1-10 plasmid was linearized with BamHI which cuts between the *GAL1* promoter and the *ADH1* transcription terminator and ligated with the 1.5 kbp, HPV6/11 L1 gene fragment (sample D361-1). *E. coli* DH5 (Gibco BRL, Inc.) transformants were screened and a pGAL1-10 plasmid containing the HPV6/11 L1 gene was isolated and designated as D362-1.

The wild-type HPV11 (wt-HPV11) DNA was cloned from a condyloma acuminatum lesion (kind gift of Dr. Darron Brown). Total human genomic DNA was extracted and digested with restriction endonucleases. The fraction containing wt-HPV11 DNA was ligated into an *E. coli* cloning vector to be used as a template for PCR. The wt-HPV11 L1 gene was amplified by PCR using Vent polymerase (New England Biolabs, Inc.), 10 cycles of amplification (94°C 1 min, 48°C 1 min, 72°C 1 min 45 sec), and the following oligonucleotide primers which contain flanking Bgl II sites (underlined):

sense primer: 5'-CTC <u>AGA TCT</u> CAC AAA ACA AAA TGT GGC GGC CTA GCG ACA GCA CAG-3' (SEQ ID NO:29)

antisense primer: 5'-GAG <u>AGA TCT</u> TAC TTT TTG GTT TTG GTA CGT TTT CG-3' (SEQ ID NO:30)

The sense primer introduces a yeast non-translated leader sequence (Kniskern, P.J. *et al.*, 1986, *Gene* 46: 135-141) immediately upstream to the wt-HPV11 L1 initiating methionine codon (highlighted in bold print). The 1.5 kbp wt-HPV11 L1 PCR product was digested with BglII, gel purified and ligated with the BamHI digested pGAL1-10 plasmid to yield plasmid, p329-1.

Total genomic DNA was extracted from an HPV6a-positive, condyloma acuminatum lesion (kind gift of Dr. Darron Brown). The HPV6a L1 gene was amplified by PCR using the biopsy sample DNA as a template, Vent polymerase (New England Biolabs, Inc.), 35 cycles of amplification (94°C 1 min, 48°C 1 min, 72°C 1 min 45 sec), the sense

primer listed above for PCR of wt-HPV11 L1 and an antisense primer with the sequence,

5'-GAG AGA TCT TAC CTT TTA GTT TTG GCG CGC TTA C-3' (SEQ ID NO:31).

The 1.5 kbp HPV6a L1 PCR product was digested with BglII, gel purified and ligated with the BamHI digested pGAL1-10 plasmid to yield plasmid D128.

## EXAMPLE 5

### Preparation of Strain 1558

Step a: Preparation of Yeast Strain U9

*Saccharomyces cerevisiae* strain 2150-2-3 (*MATalpha, leu2-04, ade1*, cir°) was obtained from Dr. Leland Hartwell (University of Washington, Seattle, WA). Cells of strain 2150-2-3 were propagated overnight at 30°C in 5 mL of YEHD medium (Carty *et al., J. Ind Micro* 2 (1987) 117-121). The cells were washed 3 times in sterile, distilled water, resuspended in 2 mL of sterile distilled water, and 0.1 mL of cell suspension was plated onto each of six 5-fluoro-orotic acid (FOA) plates in order to select for *ura3* mutants (Cold Spring Harbor Laboratory Manual for Yeast Genetics). The plates were incubated at 30°C. The medium contained per 250 mL distilled water: 3.5 g, Difco Yeast Nitrogen Base without amino acids and ammonium sulfate; 0.5 g 5-Fluoro-orotic acid; 25 mg Uracil; and 10.0 g Dextrose.

The medium was sterilized by filtration through 0.2 µm membranes and then mixed with 250 mL of 4% Bacto-Agar (Difco) maintained at 50°C, 10 mL of a 1.2 mg/mL solution of adenine, and 5 mL of L-leucine solution (180 mg/ 50 mL). The resulting medium was dispensed at 20 mL per petri dish.

After 5 days of incubation, numerous colonies had appeared. Single colonies were isolated by restreaking colonies from the initial FOA plates onto fresh FOA plates which were then incubated at 30°C. A

number of colonies from the second set of FOA plates were tested for the presence of the *ura3* mutation by replica-plating onto both YEHD plates and uracil-minus plates. The desired result was good growth on YEHD and no growth on uracil-minus medium. One isolate (U9) was obtained which showed these properties. It was stored as a frozen glycerol stock (strain #325) at -70°C for later use.

Step b: Preparation of a Vector for disruption of the Yeast *MNN9* gene

In order to prepare a vector for disruption of the *MNN9* gene, it was necessary to first clone the *MNN9* gene from *S. cerevisiae* genomic DNA. This was accomplished by standard Polymerase Chain Reaction (PCR) technology. A 5' sense primer and 3' antisense primer for PCR of the full-length *MNN9* coding sequence were designed based on the published sequence for the yeast *MNN9* gene (Zymogenetics: EPO Patent Application No. 88117834.7, Publication No. 0-314-096-A2). The following oligodeoxynucleotide primers containing flanking HindIII sites (underlined) were used:

sense primer: 5'-CTT AAA GCT TAT GTC ACT TTC TCT TGT ATC G-3' (SEQ ID NO:32)

antisense primer: 5'-TGA TAA GCT TGC TCA ATG GTT CTC TTC CTC-3'. (SEQ ID NO:33)

The initiating methionine codon for the MNN9 gene is highlighted in bold print. The PCR was conducted using genomic DNA from *S. cerevisiae* strain JRY188 as template, Taq DNA polymerase (Perkin Elmer) and 25 cycles of amplification (94°C 1 min., 37°C 2 min., 72°C 3 min.). The resulting 1.2 kbp PCR fragment was digested with HindIII, gel-purified, and ligated with HindIII-digested, alkaline-phosphatase treated pUC13 (Pharmacia). The resulting plasmid was designated p1183.

In order to disrupt the MNN9 gene with the yeast *URA3* gene, the plasmid pBR322-URA3 (which contains the 1.1 Kbp HindIII fragment encoding the *S. cerevisiae URA3* gene subcloned into the HindIII site of pBR322) was digested with HindIII and the 1.1 kbp DNA fragment bearing the functional *URA3* gene was gel-purified, made blunt-ended with T4 DNA polymerase, and then ligated with PmlI-digested plasmid p1183 (PmlI cuts within the MNN9 coding sequence). The resulting plasmid p1199 contains a disruption of the *MNN9* gene by the functional *URA3* gene.

Step c: Construction of U9-derivative strain 1372 containing disruption of *MNN9* gene

For disruption of the *MNN9* gene in strain U9 (#325), 30 µg of plasmid p1199 were digested with HindIII to create a linear *mnn9::URA3* disruption cassette. Cells of strain 325 were transformed with the HindIII-digested p1199 DNA by the spheroplast method (Hinnen *et al.*, 1978, *Proc. Natl. Acad. Sci. USA* 75:1929-1933) and transformants were selected on a synthetic agar medium lacking uracil and containing 1.0 M sorbitol. The synthetic medium contained, per liter of distilled water: Agar, 20 g; Yeast nitrogen base w/o amino acids, 6.7 g; Adenine, 0.04 g; L-tyrosine, 0.05 g; Sorbitol, 182 g; Glucose, 20 g; and Leucine Minus Solution #2, 10 ml. Leucine Minus Solution #2 contains per liter of distilled water: L-arginine, 2 g; L-histidine, 1 g; L-Leucine, 6 g; L-Isoleucine, 6 g; L-lysine, 4 g; L-methionine, 1 g; L-phenylalanine, 6 g; L-threonine, 6 g; L-tryptophan, 4 g.

The plates were incubated at 30°C for five days at which time numerous colonies had appeared. Chromosomal DNA preparations were made from 10 colonies and then digested with EcoRI plus HindIII. The DNA digests were then evaluated by Southern blots (J. Sambrook *et al.*, Molecular Cloning: A Laboratory Manual, 2nd edition, Cold Spring Harbor Laboratory Press, 1989) using the 1.2 kbp HindIII fragment bearing the *MNN9* gene (isolated from plasmid p1199) as a probe. An isolate was identified (strain #1372) which showed the expected DNA

band shifts on the Southern blot as well as the extreme clumpiness typically shown by *mnn9* mutants.

Step d: Construction of a Vector for Disruption of Yeast *HIS3* Gene

In order to construct a disruption cassette in which the *S. cerevisiae HIS3* gene is disrupted by the *URA3* gene, the plasmid YEp6 (K. Struhl *et al.*, 1979, *Proc. Natl. Acad. Sci., USA* 76:1035) was digested with BamHI and the 1.7 kbp BamHI fragment bearing the *HIS3* gene was gel-purified, made blunt-ended with T4 DNA polymerase, and ligated with pUC18 which had been previously digested with BamHI and treated with T4 DNA polymerase. The resulting plasmid (designated p1501 or pUC18-HIS3) was digested with NheI (which cuts in the *HIS3* coding sequence), and the vector fragment was gel-purified, made blunt-ended with T4 DNA polymerase, and then treated with calf intestine alkaline phosphatase. The *URA3* gene was isolated from the plasmid pBR322-URA3 by digestion with HindIII and the 1.1 kbp fragment bearing the *URA3* gene was gel-purified, made blunt-ended with T4 DNA polymerase, and ligated with the above pUC18-HIS3 NheI fragment. The resulting plasmid (designated pUC18-his3::URA3 or p1505) contains a disruption cassette in which the yeast *HIS3* gene is disrupted by the functional *URA3* gene.

Step e: Construction of Vector for Disruption of Yeast *PRB1* Gene by the *HIS3* Gene

Plasmid FP8ΔH bearing the *S. cerevisiae PRB1* gene was provided by Dr. E. Jones of Carnegie-Mellon Univ. (C. M. Moehle *et al.*, 1987, *Genetics* 115:255-263). It was digested with HindIII plus XhoI and the 3.2 kbp DNA fragment bearing the *PRB1* gene was gel-purified and made blunt-ended by treatment with T4 DNA polymerase. The plasmid pUC18 was digested with BamHI, gel-purified and made blunt-ended by treatment with T4 DNA polymerase. The resulting vector fragment was ligated with the above *PRB1* gene fragment to yield the plasmid pUC18-PRB1. Plasmid YEp6, which contains the *HIS3* gene, was digested with BamHI. The resulting 1.7 kbp BamHI fragment bearing the functional

*HIS3* gene was gel-purified and then made blunt-ended by treatment with T4 DNA polymerase. Plasmid pUC18-PRB1 was digested with EcoRV plus NcoI which cut within the *PRB1* coding sequence and removes the protease B active site and flanking sequence. The 5.7 kbp EcoRV-NcoI fragment bearing the residual 5' and 3'-portions of the *PRB1* coding sequence in pUC18 was gel-purified, made blunt-ended by treatment with T4 DNA polymerase, dephosphorylated with calf intestine alkaline phosphatase, and ligated with the blunt-ended *HIS3* fragment described above. The resulting plasmid (designated pUC18-prb1::HIS3, stock #1245) contains the functional *HIS3* gene in place of the portion of the *PRB1* gene which had been deleted above.

Step f: Construction of a U9-related Yeast Strain containing disruptions of both the *MNN9* and *PRB1* Genes

The U9-related strain 1372 which contains a *MNN9* gene disruption was described in Example 5c. Clonal isolates of strain 1372 were passaged on FOA plates (as described in Example 5a) to select *ura3* mutants. A number of *ura3* isolates of strain 1372 were obtained and one particular isolate (strain 12930-190-S1-1) was selected for subsequent disruption of the *HIS3* gene. The pUC18-his3::URA3 gene disruption vector (p1505) was digested with XbaI plus EcoRI to generate a linear *his3::URA3* disruption cassette and used for transformation of strain 12930-190-S1-1 by the lithium acetate method (Methods in Enzymology, 194:290 (1991). $Ura^+$ transformants were selected on synthetic agar medium lacking uracil, restreaked for clonal isolates on the same medium, and then replica-plated onto medium lacking either uracil or histidine to screen for those isolates that were both $Ura^+$ and $His^-$. One isolate (strain 12930-230-1) was selected for subsequent disruption of the *PRB1* gene. The *PRB1* gene disruption vector (pUC18-prb1::HIS3, stock #1245) was digested with SacI plus XbaI to generate a linear *prb1::HIS3* disruption cassette and used for transformation of strain 12930-230-1 by the lithium acetate method. $His^+$ transformants were selected on agar medium lacking histidine and restreaked on the same medium for clonal isolates. Genomic DNA was prepared from a number of the resulting

His+ isolates, digested with EcoRI, and then electrophoresed on 0.8% agarose gels. Southern blot analyses were then performed using a radio-labeled 617 bp probe for the *PRB1* gene which had been prepared by PCR using the following oligodeoxynucleotide primers:

5' TGG TCA TCC CAA ATC TTG AAA 3' (SEQ ID NO:34); and

5' CAC CGT AGT GTT TGG AAG CGA 3' (SEQ ID NO:35)

Eleven isolates were obtained which showed the expected hybridization of the probe with a 2.44 kbp *prb1::HIS3* DNA fragment. This was in contrast to hybridization of the probe with the 1.59 kbp fragment for the wild-type *PRB1* gene. One of these isolates containing the desired *prb1::HIS3* disruption was selected for further use and was designated strain #1558.

## EXAMPLE 6

### Expression of HPV11 L1 and HPV6 L1 in Yeast

Plasmids D362-1 (pGAL1-10 + HPV6/11 L1), p329-1 (pGAL1-10 + wt-HPV11 L1), D128 (pGAL1-10 + HPV6 L1) and pGAL1-10 were used to transform *S. cerevisiae* strain #1558 (*MATa, leu2-04, prb1::HIS3, mnn9::URA3, ade1, cir$^0$*) by the spheroplast method (Hinnen *et al.*, 1978, *Proc. Natl. Acad. Sci. USA* 75, 1929-1933). The #1558 yeast strain transformed with plasmid D362-1 was designated as strain #1782. For RNA studies, yeast clonal isolates were grown at 30°C in YEH complex medium (Carty *et al.*, 1987, *J. Ind. Micro.* 2, 117-121) containing 0.1 M sorbitol and either 2% glucose or galactose for 26 hours. After harvesting the cells, yeast RNA was extracted using the hot acidic phenol method as described (Current Protocols in Molecular Biology, vol. 2, Current Protocols, 1993). For protein analysis, the identical isolates were grown at 30°C in YEH complex medium containing 0.1 M sorbitol, 2% glucose and 2% galactose for 70 hours. After harvesting the cells, the cell pellets were broken with glass beads

and cell lysates analyzed for the expression of HPV11 L1 or HPV6 L1 protein by immunoblot analysis.

## EXAMPLE 7

Northern Blot Analysis of Yeast Expressed HPV L1 RNAs

Samples containing 10 µg of total RNA were denatured by treatment with glyoxal and DMSO (Current Protocols in Molecular Biology, vol. 1, Current Protocols, 1993) and electrophoresed through a phosphate-buffered, 1.2% agarose gel. The RNA was transferred onto a nylon membrane and detected with a $^{32}$P-labeled oligonucleotide that is complementary to both the HPV11 and HPV6 L1 DNA sequences.

The Northern blot is shown in Figure 4. No bands that correspond to the expected size for full-length HPV L1 RNA were detected in the samples grown on glucose medium (lanes 1,3 and 5). This is expected since glucose represses transcription from the yeast GAL 1 promoter. In contrast, samples grown in galactose medium which induces transcription from the GAL1 promoter, show strong HPV L1 RNA signals. The HPV6 L1 was transcribed as a full-length RNA species (lane 2) while the majority of the wild-type (wt)-HPV11 L1 was transcribed as a truncated form (lane 4). This result suggested that a yeast transcription termination signal is located within the wt-HPV11 L1 ORF but is not present in the HPV6 L1 sequence. The RNA transcribed from the HPV6/11 hybrid gene appears to be full-length (lane 6). No HPV specific RNA is detected in the pGAL1-10 control yeast sample (lane 7).

## EXAMPLE 8

Western Analysis of Yeast Expressed HPV L1 Proteins

Samples containing 20 µg of total cellular protein were electrophoresed through 10% Tris-Glycine gels (Novex, Inc.) under denaturing conditions and electroblotted onto nitrocellulose filters. L1 protein was immunodetected using rabbit antiserum raised against a *trpE*-HPV11 L1 fusion protein as primary antibody (Brown, D.R. *et al.*, 1994, *Virology* 201:46-54) and horseradish peroxidase (HRP)-linked donkey

anti-rabbit IgG (Amersham, Inc.) as secondary antibody. The filters were processed using the chemiluminescent ECL™ Detection Kit (Amersham, Inc.). A 50-55 kDa L1 protein band was detected in all samples except the pGAL1-10 negative control (lane 4) (Figure 5). Furthermore, the amount of HPV11 L1 protein expressed by the HPV6/11 hybrid gene (lane 3) appears to be ~10-fold greater than the amount of L1 protein expressed by either the wt-HPV11 gene (lane 2) or the HPV6 L1 gene (lane 1).

## EXAMPLE 9

ELISA of Yeast Expressed HPV11 L1 VLPs

An ELISA was used to determine relative amounts of VLPs produced from yeast clones expressing either wt-HPV11 or the HPV6/11 hybrid. The ELISA was also used to demonstrate that a conformational epitope giving rise to strongly neutralizing antibody responses was retained on the VLPs derived from the HPV6/11 hybrid DNA. This conformational epitope has been defined by monoclonal antibody H11.B2 (Christensen et al 1990, *J. Virol.* 64, 5678-5681) which is available from Chemicon International (Temecula, CA) as Chemicon Mab8740. Briefly, wells of ELISA plates (Maxisorb, Nunc Inc., Naperville, IL) were coated with decreasing amounts of total yeast protein containing the HPV6/ 11 (hybrid) or wt-HPV11 VLPs in 100 µL PBS. CsCl-purified wt-HPV11 virions (a generous gift of Dr. D. Brown) and control yeast protein were used as controls. The plates were incubated overnight at 4°C before aspirating and blocking the plates with 250 mcl 10% dried milk (Carnation) in TTBS (50 mM Tris, pH 7.6, 150 mM NaCl, 0.1% Tween20) for 2 hrs at room termperature. The plates were washed once with PBS/0.1%Tween 20 before incubating the wells with 100 mcl of a 1:1000 dilution of the anti-HPV11 virion monoclonal antibody Chemicon MAB 8740 in 1% dried milk in TTBS for 1 hr at room temperature. Plates were washed 3 times with PBS/Tween 20 and then incubated with 100 mcl of anti-mouse IgG coupled to alkaline phosphatase (Kierkegard &Perry, Gaithersburg, MD) at a dilution of 1:1000 in 1% milk + TTBS for 1 hr at room temperature. Plates were again washed 3 times with

PBS/Tween 20 before adding 100 mcl of phosphatase substrate (p-nitrophenyl phosphate in diethanolamine buffer). Plates were incubated 30 min at room temperature. The reaction was stopped by addition of 50 mcl of 3N NaOH. Plates were read at 405 nm in an ELISA plate reader.

The average OD405 nm readings of 2 wells corrected against the background readings obtained from control yeast proteins were plotted against the total yeast protein in the wells and are shown in Figure 6. The HPV6/11 hybrid yeast clone produced more than 10 times the amount of native VLPs compared to the wt clone. In addition, the strongly neutralizing epitope recognized by Chemicon Mab 8740 is displayed on these VLPs.

## EXAMPLE 10

Electron Microscopic Studies

For EM analysis (Structure Probe, West Chester, PA), an aliquot of each sample (crude clarified lysate or purified VLPs) was placed on 200-mesh carbon-coated copper grids. A drop of 2% phosphotungstic acid (PTA), pH 7.0 was placed on the grid for 20 seconds. The grids were allowed to air dry prior to transmission EM examination. All microscopy was done using a JEOL 100CX transmission electron microscope (JEOL USA, Inc.) at an accelerating voltage of 100 kV. The micrographs generated have a final magnification of 100,000x. As shown in Figure 7, VLPs were observed in the 45-55 nm diameter size range in all HPV11 samples but not in yeast control samples.

## EXAMPLE 11

Fermentation of HPV6/11 L1 (Strain #1782)

Surface growth of a plate culture of strain 1782 was aseptically transferred to a leucine-free liquid medium containing (per L): 8.5 g Difco yeast nitrogen base without amino acids and ammonium sulfate; 0.2 g adenine; 0.2 g uracil; 10 g succinic acid; 5 g ammonium sulfate; and 0.25 g L tyrosine; this medium was adjusted to pH 5.0-5.3

with NaOH prior to sterilization. After growth for 25 hr at 28°C, 250 rpm on a rotary shaker, frozen culture vials were prepared by adding sterile glycerol to a final concentration of 17% (w/v) prior to storage at - 70°C (1 mL per cryovial). Inoculum for fermentation of strain 1782 was developed in the same medium (750 mL per 2-L flask) and was started by transferring the thawed contents of two frozen culture vials to the 2-L flasks and incubating at 28°C, 250 rpm on a rotary shaker for 25 hr. Fermentation of strain 1782 used a Chemap 23 L fermenter with a working volume of 18 L after inoculation. The production medium used contained (per L): 20 g Difco yeast extract; 10 g Sheffield HySoy peptone; 20 g glucose; 20 g galactose; the medium was adjusted to pH 5.3 prior to sterilization. The entire contents (500 mL) of the 2-L inoculum flask was transferred to the fermenter which was incubated at 28°C, 9 L air per min, 500 rpm, 3.5 psi pressure. Agitation was increased as needed to maintain dissolved oxygen levels of greater than 40% of saturation. Progress of the fermentation was monitored by offline glucose measurements (Beckman Glucose 2 Analyzer) and online mass spectrometry (Perkin-Elmer 1200). After 66 hr incubation, a cell density of 9.32 g dry cell weight per L was reached. The contents of two such fermentations (total 17.5 L broth) were pooled before cell recovery. The culture was concentrated by hollow fiber filtration (Amicon H5MP01-43 cartridge in an Amicon DC-10 filtration system) to ca. 2 L, diafiltered with 2 L phosphate-buffered saline, and concentrated further (to ca. 1 L) before dispensing into 500 mL centrifuge bottles. Cell pellets were collected by centrifugation at 8,000 rpm (Sorval GS3 rotor) for 20 min at 4°C. After decanting the supernatant, the pellets (total 358 g wet cells) were stored at - 70°C until use.

## EXAMPLE 12

Purification of Recombinant HPV Type 11 L1 Capsid Proteins

All steps were performed at 4°C unless noted.

Cells were stored frozen at -70°C. Frozen cells (wet weight = 180 g) were thawed at 20-23°C and resuspended in 900 mL "Breaking Buffer" (50 mM MOPS, pH 7.2, 500 mM NaCl, 1 mM $CaCl_2$). The

protease inhibitors AEBSF and pepstatin A were added to final concentrations of 1 mM and 1.7 µM, respectively. The cell slurry was broken at a pressure of approximately 16,000 psi by 4 passes in a M110-Y Microfluidizer (Microfluidics Corp., Newton, MA). A sufficient volume of 10% Triton X100 ® detergent (Pierce, Rockford, IL) was added to the broken cell slurry to bring the concentration of TX100 to 0.5%. The slurry was stirred for 20 hours. The Triton X100-treated lysate was centrifuged at 12,000 x g for 40 min to remove cellular debris. The supernatant liquid containing L1 protein was recovered.

The supernatant liquid was diafiltered against five volumes of 20 mM sodium phosphate, pH 7.2, 0.5 M NaCl using a 300K tangential flow membrane cassette (Filtron, Northborough, MA). The material retained by the membrane was shown by radioimmunoassay and western blotting to contain the L1 protein.

The retentate was applied to a high resolution affinity column (11.0 cm ID x 5.3 cm) of SP Spherodex (M) ® resin (IBF, Villeneuve-la-Garenne, France) equilibrated in 20 mM sodium phosphate, pH 7.2, 0.5 M NaCl. Following a wash with equilibration buffer and a step wash with 20 mM sodium phosphate, pH 7.2, 1.0 M NaCl, the L1 protein was eluted with a step wash of 20 mM sodium phosphate, pH 7.2, 2.5 M NaCl. Fractions were collected during the washes and elution. Column fractions were assayed for total protein by the Bradford method. Fractions were then analyzed by western blotting and SDS-PAGE with colloidal Coomassie detection. Fractions were also analyzed by radioimmunoassay.

SP Spherodex fractions showing comparable purity and enrichment of L1 protein were pooled.

Final product was analyzed by western blotting and SDS-PAGE with colloidal Coomassie detection. The L1 protein was estimated to be > 90% homogeneous. The identity of L1 protein was confirmed by western blotting. The final product was filtered aseptically through a 0.22 µm membrane and stored at 4°C. This process resulted in a total of 100 mg protein.

Electron microscopy analysis is performed by Structure Probe (West Chester, PA). An aliquot of sample is placed on a 200 mesh carbon-coated copper grid. A drop of 2% phosphotungstic acid, pH 7.0 is placed on the grid for 20 seconds. The grid is allowed to air dry prior to TEM examination. All microscopy is performed using a JEOL 100 CX transmission electron microscope (JEOL USA, Inc.) at an accelerating voltage of 100 kV. The micrographs generated have a final magnification of 100,000 x.

Bradford Assay for Total Protein

Total protein was assayed using a commercially available Coomassie Plus ® kit (Pierce, Rockford, IL). Samples were diluted to appropriate levels in Milli-Q-$H_2O$. Volumes required were 0.1 mL and 1.0 mL for the standard and microassay protocols, respectively. For both protocols, BSA (Pierce, Rockford, IL) was used to generate the standard curve. Assay was performed according to manufacturer's recommendations. Standard curves were plotted using CricketGraph® software on a Macintosh IIci computer.

SDS-PAGE and Western Blot Assays

All gels, buffers, and electrophoretic apparatus were obtained from Novex (San Diego, CA) and were run according to manufacturer's recommendations. Briefly, samples were diluted to equal protein concentrations in Milli-Q-$H_2O$ and mixed 1:1 with sample incubation buffer containing 200 mM DTT. Samples were incubated 15 min at 100°C and loaded onto pre-cast 12% Tris-glycine gels. The samples were electrophoresed at 125V for 1 hr 45 min. Gels were developed by colloidal Coomassie staining using a commercially obtained kit (Integrated Separation Systems, Natick, MA).

For western blots, proteins were transferred to PVDF membranes at 25V for 40 min. Membranes were washed with Milli-Q-H2O and air-dried. Primary antibody was polyclonal rabbit antiserum raised against a TrpE-HPV11L1 fusion protein (gift of Dr. D. Brown). The antibody solution was prepared by dilution of antiserum in blotting

buffer (5% non-fat milk in 6.25 mM Na phosphate, pH 7.2, 150 mM NaCl, 0.02% $NaN_3$). Incubation was for at least 1 hour at 20-23°C. The blot was washed for 1 min each in three changes of PBS (6.25 mM Na phosphate, pH 7.2, 150 mM NaCl). Secondary antibody solution was prepared by diluting goat anti-rabbit IgG alkaline phosphatase-linked conjugate antiserum (Pierce, Rockford, IL) in blotting buffer. Incubation proceeded under the same conditions for at least 1 hour. Blots were washed as before and detected using a 1 step NBT/BCIP substrate (Pierce, Rockford, IL).

## EXAMPLE 13

Preparation of Immunogenic Compositions

Purified VLP's are formulated according to known methods, such as by the admixture of pharmaceutically acceptable carriers, stabilizers, or a vaccine adjuvant. The immunogenic VLP's of the present invention may be prepared for vaccine use by combining with a physiologically acceptable composition such as, e.g. PBS, saline or distilled water. The immunogenic VLP's are administered in a dosage range of about 0.1 to 100 mcg, preferably about 1 to about 20 mcg, in order to obtain the desired immunogenic effect. The amount of VLP per formulation may vary according to a variety of factors, including but not limited to the individual's condition, weight, age and sex. Administration of the VLP formulation may be by a variety of routes, including but not limited to oral, subcutaneous, topical, mucosal and intramuscular. Such VLP formulations may be comprised of a single type of VLP (i.e., VLP from HPV11) or a mixture of VLP's (i.e, VLP's from HPV6, HPV11, HPV16 and HPV18).

An antimicrobial preservative, e.g. thimerosal, optionally may be present. The immunogenic antigens of the present invention may be employed, if desired, in combination with vaccine stabilizers and vaccine adjuvants. Typical stabilizers are specific compounds, e.g. polyanions such as heparin, inositol hexasulfate, sulfated beta-cyclodextrin, less specific excipients, e.g. amino acids, sorbitol, mannitol, xylitol, glycerol, sucrose, dextrose, trehalose, and variations in solution

conditions, e.g. neutral pH, high ionic strength (ca. 0.5-2.0 M salts), divalent cations ($Ca^{2+}$, $Mg^{2+}$). Examples of adjuvants are $Al(OH)_3$ and $Al(PO_4)$. The vaccine of the present invention may be stored under refrigeration or in lyophilized form.

## EXAMPLE 14

Preparation of Antibodies to VLP

Purified VLP are used to generate antibodies. The term "antibody" as used herein includes both polyclonal and monoclonal antibodies as well as fragments thereof, such as Fv, Fab and F(ab)2 fragments that are capable of binding antigen or hapten. The antibodies are used in a variety of ways, including but not limited to the purification of recombinant VLP, the purification of native L1 or L2 proteins, and kits. Kits would comprise a compartmentalized carrier suitable to hold in close confinement at least one container. The carrier would further comprise reagents such as the anti-VLP antibody or the VLP suitable for detecting HPV or fragments of HPV or antibodies to HPV. The carrier may also contain means for detection such as labeled antigen or enzyme substrates or the like. The antibodies or VLP or kits are useful for a variety of purposes, including but not limited to forensic analyses and epidemiological studies.

WHAT IS CLAIMED IS:

1. An isolated and purified DNA molecule encoding human papillomavirus type 11 L1 protein or a functional derivative thereof, the DNA molecule being free of internal transcription termination signals which are recognized by yeast.

2. The DNA molecule of Claim 1 having the sequence shown in Figure 8.

3. An expression vector comprising the DNA molecule of Claim 1.

4. An expression vector comprising the DNA molecule of Claim 2.

5. The expression vector of Claim 4 which is D361-2.

6. An antibody immunologically reactive with the a compound selected from the DNA molecule of Claim 1, RNA complementary to the DNA molecule of Claim 1 or a protein encoded by the DNA molecule of Claim 1.

7. Capsids comprised of protein encoded by the DNA molecule of Claim 1.

8. Virus-like particles comprised of protein encoded by the DNA molecule of Claim 1.

9. Compositions comprised of the DNA molecule of Claim 1, RNA complementary to the DNA molecule of Claim 1 or a protein encoded by the DNA molecule of Claim 1.

10. Vaccines comprised of the compositions of Claim 9.

11. A composition capable of inducing an immune response in a subject treated with the composition, the composition containing a compound selected from the DNA molecule of Claim 1, peptides encoded by the DNA molecule of Claim 1, RNA complementary to the DNA molecule of Claim 1, or combinations thereof.

12. A vaccine for the prevention or treatment of human papillomavirus infection, the vaccine containing a compound selected from the group consisting of the DNA molecule of Claim 1, peptides encoded by the DNA molecule of Claim 1, RNA complementary to the DNA molecule of Claim 1, or combinations thereof.

13. A method for inducing immune responses against infection or disease caused by human papillomavirus which comprises introducing into an animal the DNA molecule of Claim 1, RNA complementary to the DNA molecule of Claim 1, protein encoded by the DNA molecule of Claim 1, or combinations thereof.

14. Recbinant human papillomavirus type 11 L1 protein.

15. A process for production of a purified recombinant human papillomavirus type 11 L1 protein, comprising:

(a) transforming a suitable host with an expression vector comprised of a DNA molecule encoding human papillomavirus type 11 L1 protein to produce a transformed cell;

(b) cultivating the transformed cell under conditions which allow expression of the recombinant human papillomavirus type 11 L1 protein; and

(c) purifying the recombinant human papillomavirus type 11 L1 protein.

16. Recombinant human papillomavirus type 11 L1 protein produced by the process of Claim 15.

17. Virus-like particles comprised of the protein of Claim 16.

18. Compositions comprised of the purified protein of Claim 16.

19. Vaccines comprised of the purified protein of Claim 16.

20. A method of treating a patient in need of such treatment for a condition which is mediated by a human papillomavirus type 11, comprising administration of the protein of Claim 14 to the patient.

21. A method of making purified virus-like particles comprised of the protein of Claim 14, comprising:

(a) transforming a suitable host with an expression vector comprised of a DNA molecule encoding human papillomavirus type 11 L1 protein to produce a transformed cell;

(b) cultivating the transformed cell under conditions which allow expression of the recombinant human papillomavirus type 11 L1 protein;

(c) purifying the recombinant human papillomavirus type 11 L1 protein; and

(d) further purifying the protein to produce a virus-like particle.

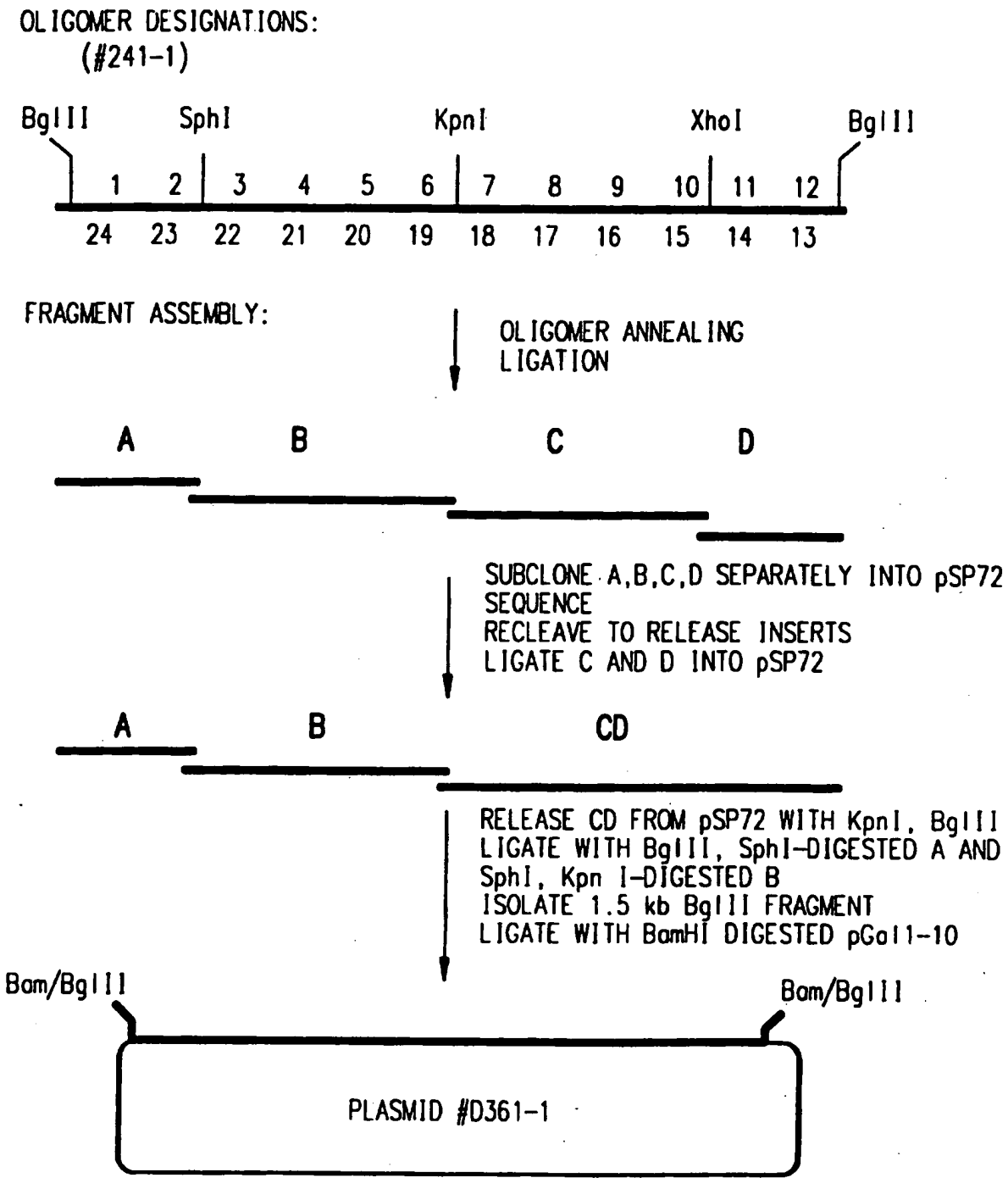
OLIGOMER DESIGNATIONS:
(#241-1)
BglII
SphI
KpnI
XhoI
BglII
1 2 3 4 5 6 7 8 9 10 11 12
24 23 22 21 20 19 18 17 16 15 14 13
FRAGMENT ASSEMBLY:
OLIGOMER ANNEALING
LIGATION
A
B
C
D
SUBCLONE A,B,C,D SEPARATELY INTO pSP72
SEQUENCE
RECLEAVE TO RELEASE INSERTS
LIGATE C AND D INTO pSP72
A
B
CD
RELEASE CD FROM pSP72 WITH KpnI, BglII
LIGATE WITH BglII, SphI-DIGESTED A AND
SphI, Kpn I-DIGESTED B
ISOLATE 1.5 kb BglII FRAGMENT
LIGATE WITH BamHI DIGESTED pGal1-10
Bam/BglII
Bam/BglII
PLASMID #D361-1

FIG. 1

```
                    10         20         30         40         50
Lowy-16L1      1 ATGTCTCTTT GGCTGCCTAG TGAGGCCACT GTCTACTTGC CTCCTGTCCC   50
hpv1611.gb     1 ATGTCTCTTT GGCTGCCTAG TGAGGCCACT GTCTACTTGC CTCCTGTCCC   50
hpv1611.mrl    1 ATGTCTCTTT GGCTGCCTAG TGAGGCCACT GTCTACTTGC CTCCTGTCCC   50

                    60         70         80         90        100
Lowy-16L1     51 AGTATCTAAG GTTGTAAGCA CGGATGAATA TGTTGCACGC ACAAACATAT  100
hpv1611.gb    51 AGTATCTAAG GTTGTAAGCA CGGATGAATA TGTTGCACGC ACAAACATAT  100
hpv1611.mrl   51 AGTATCTAAG GTTGTAAGCA CGGATGAATA TGTTGCACGC ACAAACATAT  100

                   110        120        130        140        150
Lowy-16L1    101 ATTATCATGC AGGAACATCC AGACTACTTG CAGTTGGACA TCCCTATTTT  150
hpv1611.gb   101 ATTATCATGC AGGAACATCC AGACTACTTG CAGTTGGACA TCCCTATTTT  150
hpv1611.mrl  101 ATTATCATGC AGGAACATCC AGACTACTTG CAGTTGGACA TCCCTATTTT  150

                   160        170        180        190        200
Lowy-16L1    151 CCTATTAAAA AACCTAACAA TAACAAAATA TTAGTTCCTA AAGTATCAGG  200
hpv1611.gb   151 CCTATTAAAA AACCTAACAA TAACAAAATA TTAGTTCCTA AAGTATCAGG  200
hpv1611.mrl  151 CCTATTAAAA AACCTAACAA TAACAAAATA TTAGTTCCTA AAGTATCAGG  200

                   210        220        230        240        250
Lowy-16L1    201 ATTACAATAC AGGGTATTTA GAATACATTT ACCTGACCCC AATAAGTTTG  250
hpv1611.gb   201 ATTACAATAC AGGGTATTTA GAATACATTT ACCTGACCCC AATAAGTTTG  250
hpv1611.mrl  201 ATTACAATAC AGGGTATTTA GAATACATTT ACCTGACCCC AATAAGTTTG  250

                   260        270        280        290        300
Lowy-16L1    251 GTTTTCCTGA CACCTCATTT TATAATCCAG ATACACAGCG GCTGGTTTGG  300
hpv1611.gb   251 GTTTTCCTGA CACCTCATTT TATAATCCAG ATACACAGCG GCTGGTTTGG  300
hpv1611.mrl  251 GTTTTCCTGA CACCTCATTT TATAATCCAG ATACACAGCG GCTGGTTTGG  300

                   310        320        330        340        350
Lowy-16L1    301 GCCTGTGTAG GTGTTGAGGT AGGTCGTGGT CAGCCATTAG GTGTGGGCAT  350
hpv1611.gb   301 GCCTGTGTAG GTGTTGAGGT AGGTCGTGGT CAGCCATTAG GTGTGGGCAT  350
hpv1611.mrl  301 GCCTGTGTAG GTGTTGAGGT AGGTCGTGGT CAGCCATTAG GTGTGGGCAT  350

                   360        370        380        390        400
Lowy-16L1    351 TAGTGGCCAT CCTTTATTAA ATAAATTGGA TGACACAGAA AATGCTAGTG  400
hpv1611.gb   351 TAGTGGCCAT CCTTTATTAA ATAAATTGGA TGACACAGAA AATGCTAGTG  400
hpv1611.mrl  351 TAGTGGCCAT CCTTTATTAA ATAAATTGGA TGACACAGAA AATGCTAGTG  400

                   410        420        430        440        450
Lowy-16L1    401 CTTATGCAGC AAATGCAGGT GTGGATAATA GAGAATGTAT ATCTATGGAT  450
hpv1611.gb   401 CTTATGCAGC AAATGCAGGT GTGGATAATA GAGAATGTAT ATCTATGGAT  450
hpv1611.mrl  401 CTTATGCAGC AAATGCAGGT GTGGATAATA GAGAATGTAT ATCTATGGAT  450
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FIG.2A

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                        460        470        480        490        500
Lowy-16L1    451 TACAAACAAA CACAATTGTG TTTAATTGGT TGCAAACCAC CTATAGGGGA 500
hpv1611.gb   451 TACAAACAAA CACAATTGTG TTTAATTGGT TGCAAACCAC CTATAGGGGA 500
hpv1611.mrl  451 TACAAACAAA CACAATTGTG TTTAATTGGT TGCAAACCAC CTATAGGGGA 500

                        510        520        530        540        550
Lowy-16L1    501 ACACTGGGGC AAAGGATCCC CATGTACCAA TGTTGCAGTA AATCCAGGTG 550
hpv1611.gb   501 ACACTGGGGC AAAGGATCCC CATGTACCAA TGTTGCAGTA AATCCAGGTG 550
hpv1611.mrl  501 ACACTGGGGC AAAGGATCCC CATGTACCAA TGTTGCAGTA AATCCAGGTG 550

                        560        570        580        590        600
Lowy-16L1    551 ATTGTCCACC ATTAGAGTTA ATAAACACAG TTATTCAGGA TGGTGATATG 600
hpv1611.gb   551 ATTGTCCACC ATTAGAGTTA ATAAACACAG TTATTCAGGA TGGTGATATG 600
hpv1611.mrl  551 ATTGTCCACC ATTAGAGTTA ATAAACACAG TTATTCAGGA TGGTGATATG 600

                        610        620        630        640        650
Lowy-16L1    601 GTTGATACTG GCTTTGGTGC TATGGACTTT ACTACATTAC AGGCTAACAA 650
hpv1611.gb   601 GTTCATACTG GCTTTGGTGC TATGGACTTT ACTACATTAC AGGCTAACAA 650
hpv1611.mrl  601 GTTGATACTG GCTTTGGTGC TATGGACTTT ACTACATTAC AGGCTAACAA 650

                        660        670        680        690        700
Lowy-16L1    651 AAGTGAAGTT CCACTGGATA TTTGTACATC TATTTGCAAA TATCCAGATT 700
hpv1611.gb   651 AAGTGAAGTT CCACTGGATA TTTGTACATC TATTTGCAAA TATCCAGATT 700
hpv1611.mrl  651 AAGTGAAGTT CCACTGGATA TTTGTACATC TATTTGCAAA TATCCAGATT 700

                        710        720        730        740        750
Lowy-16L1    701 ATATTAAAAT GGTGTCAGAA CCATATGGCG ACAGCTTATT TTTTTATTTA 750
hpv1611.gb   701 ATATTAAAAT GGTGTCAGAA CCATATGGCG ACAGCTTATT TTTTTATTTA 750
hpv1611.mrl  701 ATATTAAAAT GGTGTCAGAA CCATATGGCG ACAGCTTATT TTTTTATTTA 750

                        760        770        780        790        800
Lowy-16L1    751 CGAAGGGAAC AAATGTTTGT TAGACATTTA TTTAATAGGG CTGGTACTGT 800
hpv1611.gb   751 CGAAGGGAAC AAATGTTTGT TAGACATTTA TTTAATAGGG CTGGTACTGT 800
hpv1611.mrl  751 CGAAGGGAAC AAATGTTTGT TAGACATTTA TTTAATAGGG CTGGTGCTGT 800

                        810        820        830        840        850
Lowy-16L1    801 TGGTGAAAAT GTACCAGACG ATTTATACAT TAAAGGCTCT GGGTCTACTG 850
hpv1611.gb   801 TGGTGAAAAT GTACCAGACG ATTTATACAT TAAAGGCTCT GGGTCTACTG 850
hpv1611.mrl  801 TGGTGAAAAT GTACCAGACG ATTTATACAT TAAAGGCTCT GGGTCTACTG 850

                        860        870        880        890        900
Lowy-16L1    851 CAAATTTAGC CAGTTCAAAT TATTTTCCTA CACCTAGTGG TTCTATGGTT 900
hpv1611.gb   851 CAAATTTAGC CAGTTCAAAT TATTTTCCTA CACCTAGTGG TTCTATGGTT 900
hpv1611.mrl  851 CAAATTTAGC CAGTTCAAAT TATTTTCCTA CACCTAGTGG TTCTATGGTT 900
```

FIG.2B

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                        910        920        930        940        950
Lowy-16L1     901 ACCTCTGATG CCCAAATATT CAATAAACCT TATTGGTTAC AACGAGCACA  950
hpv1611.gb    901 ACCTCTGATG CCCAAATATT CAATAAACCT TATTGGTTAC AACGAGCACA  950
hpv1611.mrl   901 ACCTCTGATG CCCAAATATT CAATAAACCT TATTGGTTAC AACGAGCACA  950

                        960        970        980        990       1000
Lowy-16L1     951 GGGCCACAAT AATGGCATTT GTTGGGGTAA CCAACTATTT GTTACTGTTG 1000
hpv1611.gb    951 GGGCCACAAT AATGGCATTT GTTGGGGTAA CCAACTATTT GTTACTGTTG 1000
hpv1611.mrl   951 GGGCCACAAT AATGGCATTT GTTGGGGTAA CCAACTATTT GTTACTGTTG 1000

                       1010       1020       1030       1040       1050
Lowy-16L1    1001 TTGATACTAC ACGCAGTACA AATATGTCAT TATGTGCTGC CATATCTACT 1050
hpv1611.gb   1001 TTGATACTAC ACGCAGTACA AATATGTCAT TATGTGCTGC CATATCTACT 1050
hpv1611.mrl  1001 TTGATACTAC ACGCAGTACA AATATGTCAT TATGTGCTGC CATATCTACT 1050

                       1060       1070       1080       1090       1100
Lowy-16L1    1051 TCAGAAACTA CATATAAAAA TACTAACTTT AAGGAGTACC TACGACATGG 1100
hpv1611.gb   1051 TCAGAAACTA CATATAAAAA TACTAACTTT AAGGAGTACC TACGACATGG 1100
hpv1611.mrl  1051 TCAGAAACTA CATATAAAAA TACTAACTTT AAGGAGTACC TACGACATGG 1100

                       1110       1120       1130       1140       1150
Lowy-16L1    1101 GGAGGAATAT GATTTACAGT TTATTTTTCA ACTGTGCAAA ATAACCTTAA 1150
hpv1611.gb   1101 GGAGGAATAT GATTTACAGT TTATTTTTCA ACTGTGCAAA ATAACCTTAA 1150
hpv1611.mrl  1101 GGAGGAATAT GATTTACAGT TTATTTTTCA ACTGTGCAAA ATAACCTTAA 1150

                       1160       1170       1180       1190       1200
Lowy-16L1    1151 CTGCAGACGT TATGACATAC ATACATTCTA TGAATTCCAC TATTTTGGAG 1200
hpv1611.gb   1151 CTGCAGACGT TATGACATAC ATACATTCTA TGAATTCCAC TATTTTGGAG 1200
hpv1611.mrl  1151 CTGCAGACGT TATGACATAC ATACATTCTA TGAATTCCAC TATTTTGGAG 1200

                       1210       1220       1230       1240       1250
Lowy-16L1    1201 GACTGGAATT TTGGTCTACA ACCTCCCCCA GGAGGCACAC TAGAAGATAC 1250
hpv1611.gb   1201 GACTGGAATT TTGGTCTACA ACCTCCCCCA GGAGGCACAC TAGAAGATAC 1250
hpv1611.mrl  1201 GACTGGAATT TTGGTCTACA ACCCCCCCCA GGAGGCACAC TAGAAGATAC 1250

                       1260       1270       1280       1290       1300
Lowy-16L1    1251 TTATAGGTTT GTAAC--CC AGGCAATTGC TTGTCAAAAA CATACACCTC 1300
hpv1611.gb   1251 TTATAGGTTT GTAAC--CC AGGCAATTGC TTGTCAAAAA CATACACCTC 1300
hpv1611.mrl  1251 TTATAGGTTT GTAACATCCC AGGCAATTGC TTGTCAAAAA CATACACCTC 1300

                       1310       1320       1330       1340       1350
Lowy-16L1    1301 CAGCACCTAA AGAAGATGAT CCCCTTAAAA AATACACTTT TTGGGAAGTA 1350
hpv1611.gb   1301 CAGCACCTAA AGAAGATGAT CCCCTTAAAA AATACACTTT TTGGGAAGTA 1350
hpv1611.mrl  1301 CAGCACCTAA AGAAGAT-- CCCCTTAAAA AATACACTTT TTGGGAAGTA 1350
```

FIG 2C

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                          1360       1370       1380       1390       1400
Lowy-16L1    1351 AATTTAAAGG AAAAGTTTTC TGCAGACCTA GATCAGTTTC CTTTAGGACG 1400
hpv1611.gb   1351 AATTTAAAGG AAAAGTTTTC TGCAGACCTA GATCAGTTTC CTTTAGGACG 1400
hpv1611.mrl  1351 AATTTAAAGG AAAAGTTTTC TGCAGACCTA GATCAGTTTC CTTTAGGACG 1400

                          1410       1420       1430       1440       1450
Lowy-16L1    1401 CAAATTTTTA CTACAAGCAG GATTGAAGGC CAAACCAAAA TTTACATTAG 1450
hpv1611.gb   1401 CAAATTTTTA CTACAAGCAG GATTGAAGGC CAAACCAAAA TTTACATTAG 1450
hpv1611.mrl  1401 CAAATTTTTA CTACAAGCAG GATTGAAGGC CAAACCAAAA TTTACATTAG 1450

                          1460       1470       1480       1490       1500
Lowy-16L1    1451 GAAAACGAAA AGCTACACCC ACCACCTCAT CTACCTCTAC AACTGCTAAA 1500
hpv1611.gb   1451 GAAAACGAAA AGCTACACCC ACCACCTCAT CTACCTCTAC AACTGCTAAA 1500
hpv1611.mrl  1451 GAAAACGAAA AGCTACACCC ACCACCTCAT CTACCTCTAC AACTGCTAAA 1500

                          1510       1520       1530       1540       1550
Lowy-16L1    1501 CGCAAAAAAC GTAAGCTGTA ..........  ..........  .......... 1550
hpv1611.gb   1501 CGCAAAAAAC GTAAGCTGTA A.........  ..........  .......... 1550
hpv1611.mrl  1501 CGCAAAAAAC GTAAGCTGTA A.........  ..........  .......... 1550
```

FIG.2D

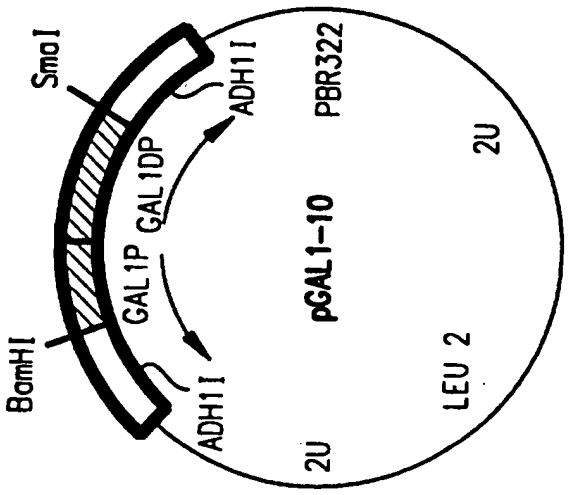
SmaI
BamHI
ADH1 I
GAL 1P
GAL 1DP
ADH1 I
pGAL1-10
PBR322
2U
LEU 2
2U

FIG.3

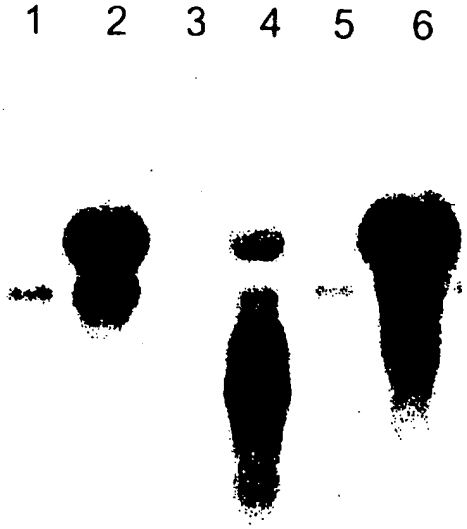


FIG.4

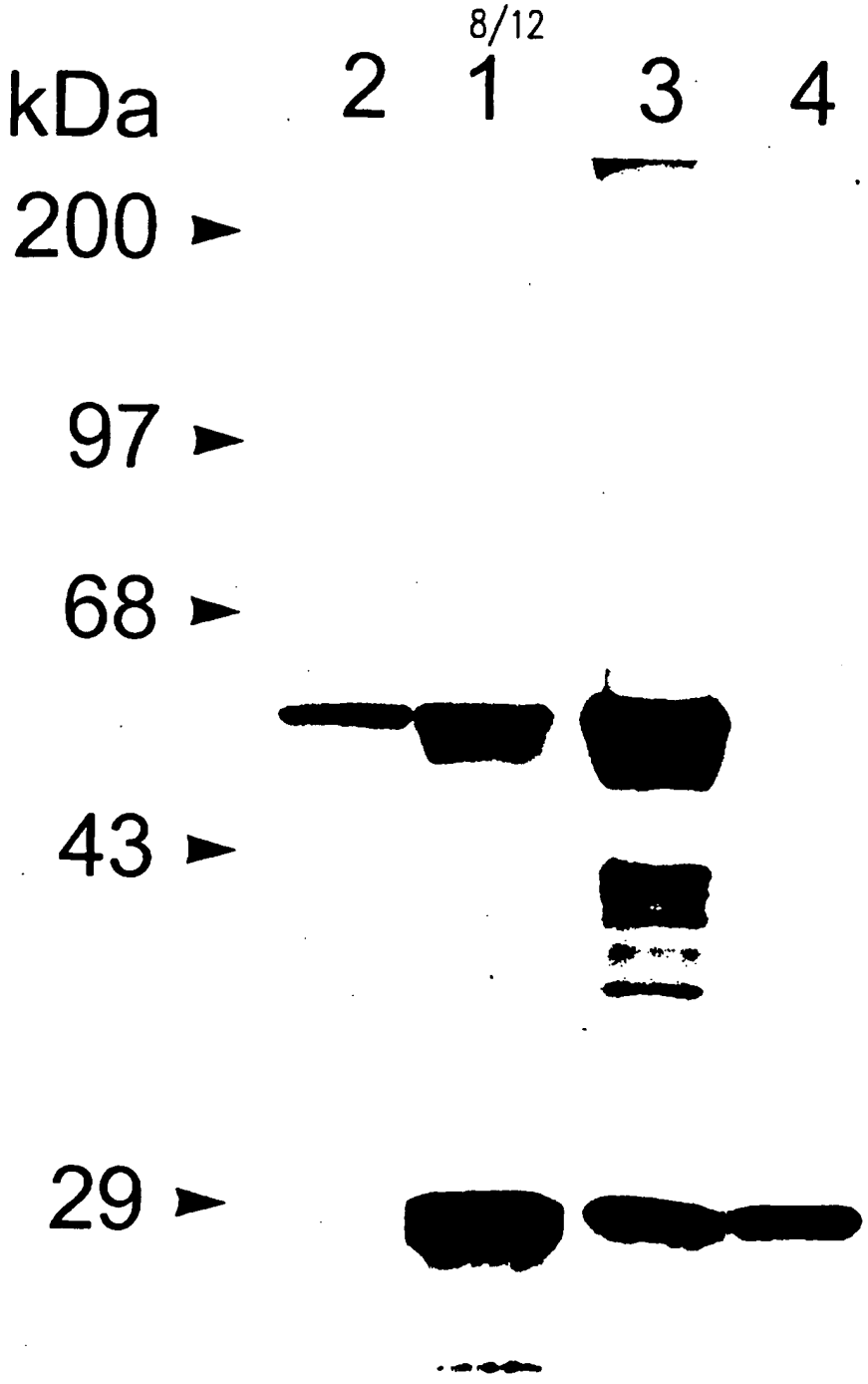


FIG.5

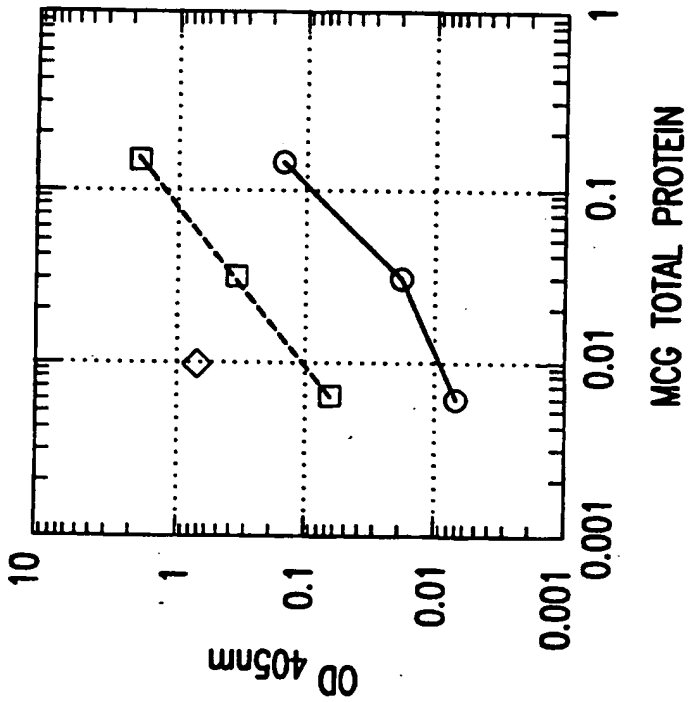


FIG.6

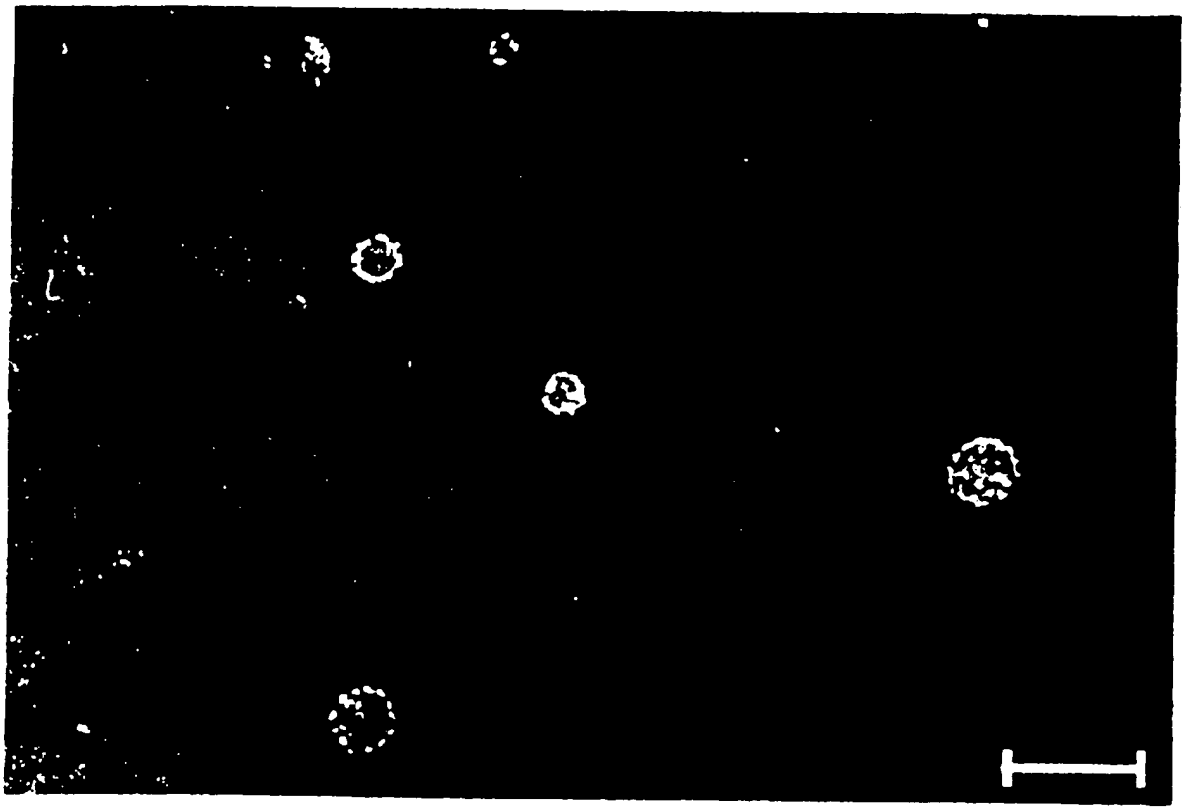

FIG.7

```
        10          20          30          40          50          60
ATGTGGCGGC CTAGCGACAG CACAGTATAT GTGCCTCCTC CTAACCCTGT ATCCAAAGTT
        70          80          90         100         110         120
GTTGCCACGG ATGCTTATGT TAAACGCACC AACATATTTT ATCATGCCAG CAGTTCTAGA
       130         140         150         160         170         180
CTTCTTGCAG TGGGTCATCC TTATTATTCC ATAAAAAAGG TTAACAAAAC TGTTGTGCCA
       190         200         210         220         230         240
AAGGTGTCAG GATATCAATA CAGAGTATTT AAGGTGGTGT TACCAGATCC TAACAAATTT
       250         260         270         280         290         300
GCATTGCCTG ACTCGTCTCT TTTTGATCCC ACAACACAAC GTTTGGTATG GGCATGCACA
       310         320         330         340         350         360
GGCCTAGAGG TGGGCCGGGG ACAGCCATTA GGTGTGGGTG TAAGTGGACA TCCTTTACTA
       370         380         390         400         410         420
AATAAATATG ATGATGTTGA AAATTCAGGG GGTTACGGTG GTAACCCTGG ACAGGATAAC
       430         440         450         460         470         480
AGGGTTAATG TAGGTATGGA TTATAAACAA ACACAATTAT GCATGGTTGG ATGTGCCCCC
       490         500         510         520         530         540
CCTTTGGGCG AGCATTGGGG TAAAGGTACA CAGTGTAGTA ATACATCTGT ACAGAATGGT
       550         560         570         580         590         600
GACTGCCCGC CCTTAGAACT TATTACCAGT GTTATACAGG ATGGCGATAT GGTTGACACA
       610         620         630         640         650         660
GGCTTTGGTG CTATGAATTT TGCTGATTTG CAGACCAATA AATCAGATGT TCCTCTTGAC
       670         680         690         700         710         720
ATATGTGGCA CTGTATGTAA ATATCCAGAT TATTTACAAA TGGCTGCAGA CCCATATGGT
       730         740         750         760         770         780
GATAGATTAT TTTTTTATCT ACGGAAGGAA CAAATGTTTG CCAGACATTT TTTTAACAGG
       790         800         810         820         830         840
GCTGGTACCG TGGGGGAACC TGTGCCTGAT GATCTTTTAG TTAAGGGTGG TAACAATCGC
       850         860         870         880         890         900
TCGTCTGTAG CGAGTAGTAT ATATGTTCAC ACCCCAAGCG GCTCTTTGGT GTCCTCTGAG
       910         920         930         940         950         960
GCACAATTGT TTAATAAGCC ATATTGGCTA CAAAAAGCCC AGGGACATAA CAATGGTATT
       970         980         990        1000        1010        1020
TGTTGGGGTA ATCATCTGTT TGTTACTGTG GTAGATACCA CACGCAGTAC CAACATGACA
      1030        1040        1050        1060        1070        1080
TTATGTGCAT CCGTATCTAA ATCTGCCACA TACACCAATT CTGATTATAA AGAGTACATG
      1090        1100        1110        1120        1130        1140
CGTCATGTGG AAGAGTTTGA TTTACAATTT ATTTTTCAAT TATGTAGCAT TACATTGTCT
      1150        1160        1170        1180        1190        1200
GCTGAAGTAA TGGCCTATAT TCACACAATG AATCCCTCTG TTCTCGAAGA CTGGAACTTT
      1210        1220        1230        1240        1250        1260
GGGTTATCGC CTCCCCCAAA TGGTACACTC GAGGATACCT ATAGGTATGT GCAGTCACAG
```

FIG. 8A

```
      1270        1280        1290        1300        1310        1320
GCCATTACCT GTCAAAAGCC CACTCCTGAA AAGGAAAAGC AAGATCCCTA TAAGGACATG
      1330        1340        1350        1360        1370        1380
AGTTTTTGGG AGGTTAATTT AAAAGAAAAG TTTTCTAGTG AATTGGATCA GTTTCCTTTG
      1390        1400        1410        1420        1430        1440
GGACGCAAGT TTTTGTTACA AAGTGGATAT AGGGGACGGA CCTCTGCTCG TACCGGTATT
      1450        1460        1470        1480        1490        1500
AAGCGCCCTG CTGTTTCCAA ACCCTCTACT GCCCCTAAAC GTAAGCGCAC CAAAACTAAA
      1510        1520        1530        1540        1550        1560
AAGTAA.... .......... .......... .......... .......... ..........
```

FIG. 8B